Shuvo Mohajon
DMC, KTG
4th year

Class XII Academic Program-2020

BIOLOGY

Lecture : B-16

Chapter 9 : Plant Physiology

Photosynthesis

Photosynthesis

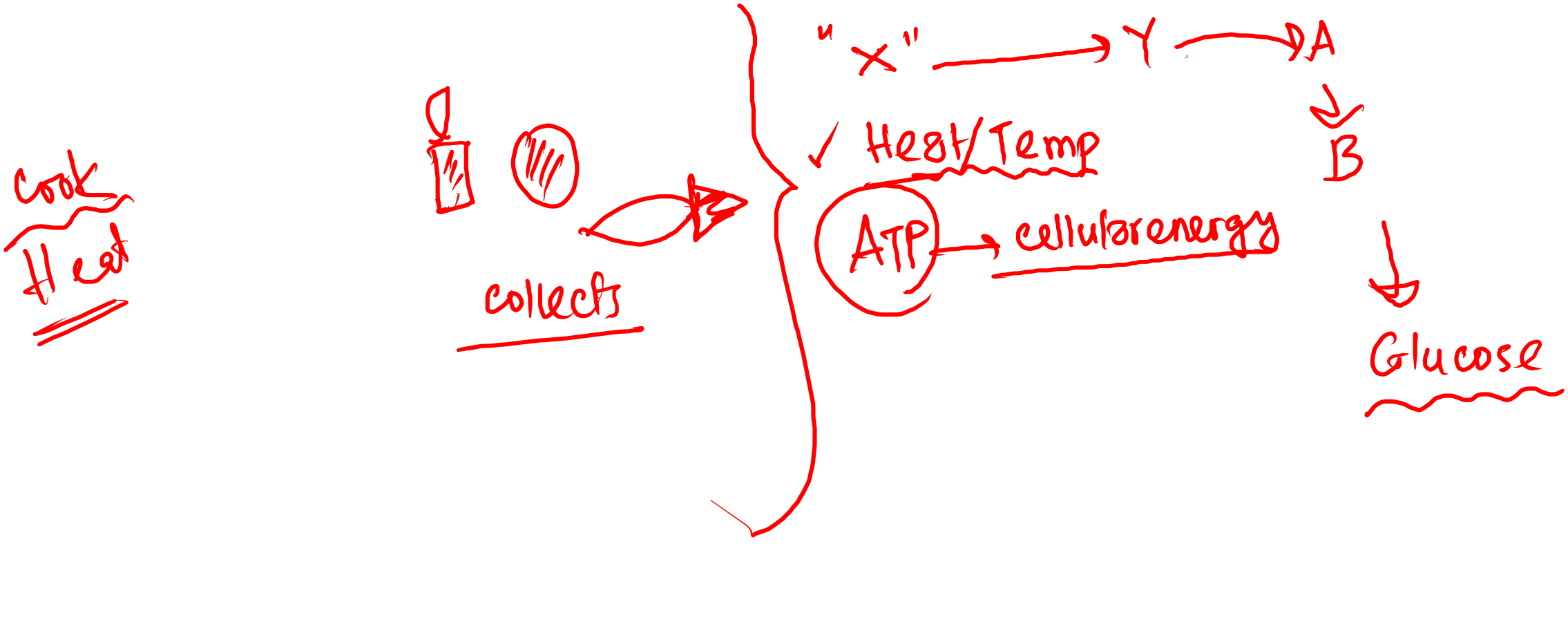
- This process requires CO_2, water, sunlight and chlorophyll. Carbohydrate or sugar and O_2 are produced. CO_2 is used to make carbohydrate and water is used as chemical energy to produce $NADPH+H^+$. Sunlight is needed for energy and chlorophyll is needed for absorption of light energy and converting it to chemical energy. It is a physiological process.

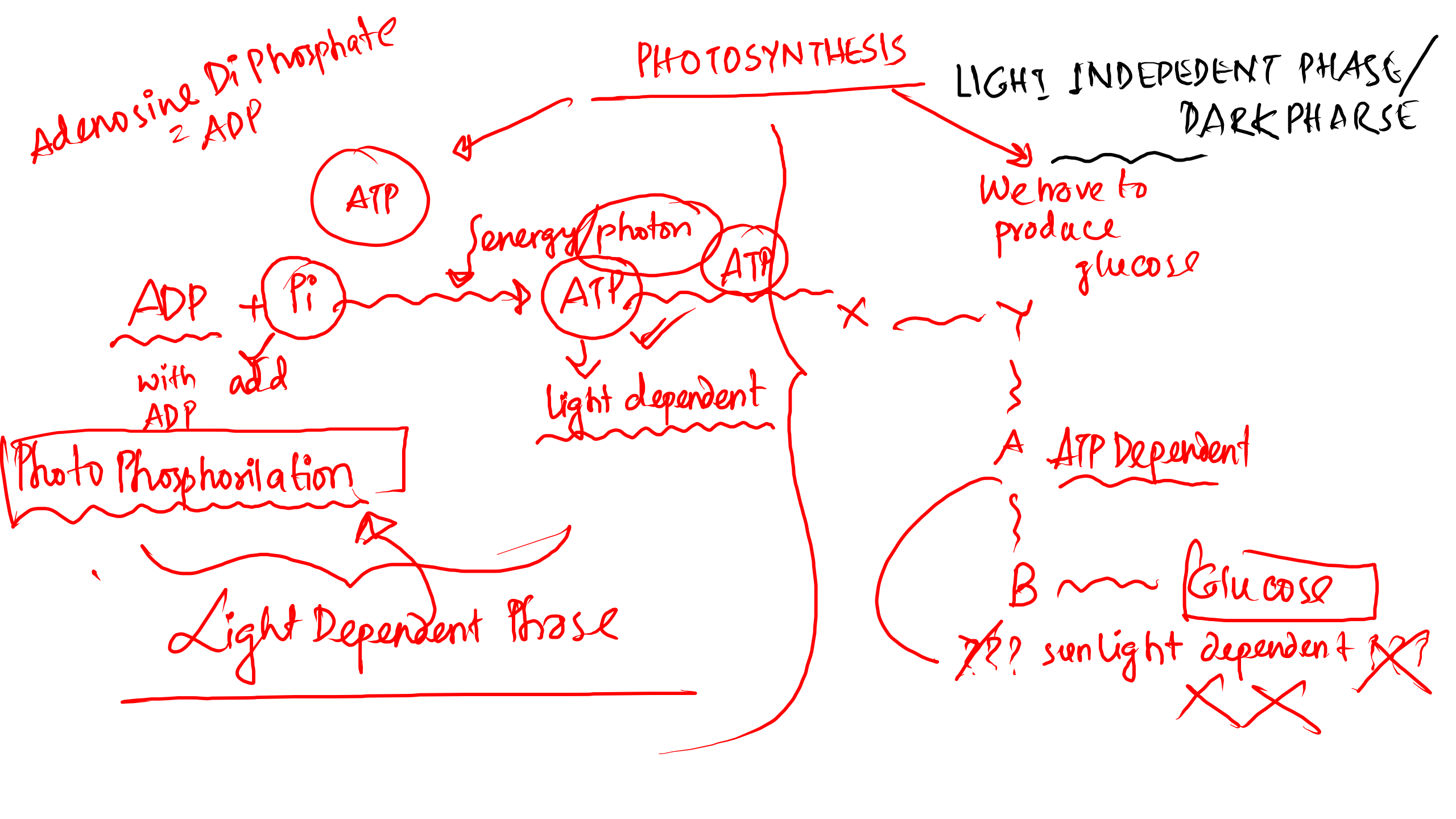
REAL EXAMPLE

PHOTO-SYNTHESIS

PHOTO - BIO - SYNTHESIS

PHOTON ⇝ GLUCOSE FORMATION




Adenosine Di Phosphate
2 ADP
PHOTOSYNTHESIS
LIGHT INDEPENDENT PHASE/
DARK PHARSE
ATP
Senergy/photon
ATP
ATP
We have to
produce
glucose
ADP + Pi
with ADP
add
Light dependent
X
Y
Photo Phosphorilation
A
ATP Dependent
B
Glucose
Light Dependent Phase
??? sunlight dependent ???

PHOTOLYSIS OF WATER:

LYSIS = BREAKDOWN

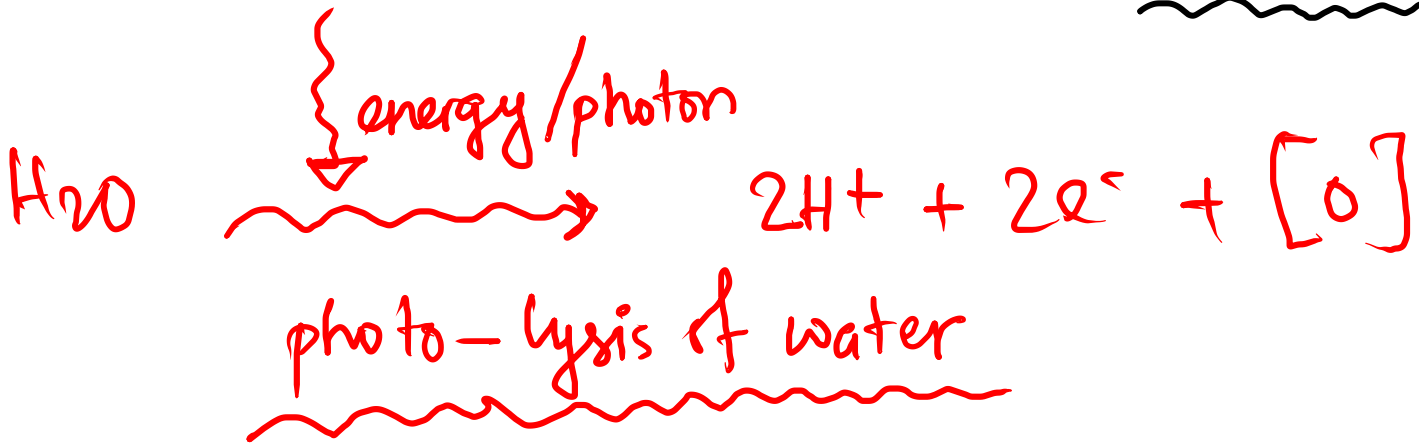
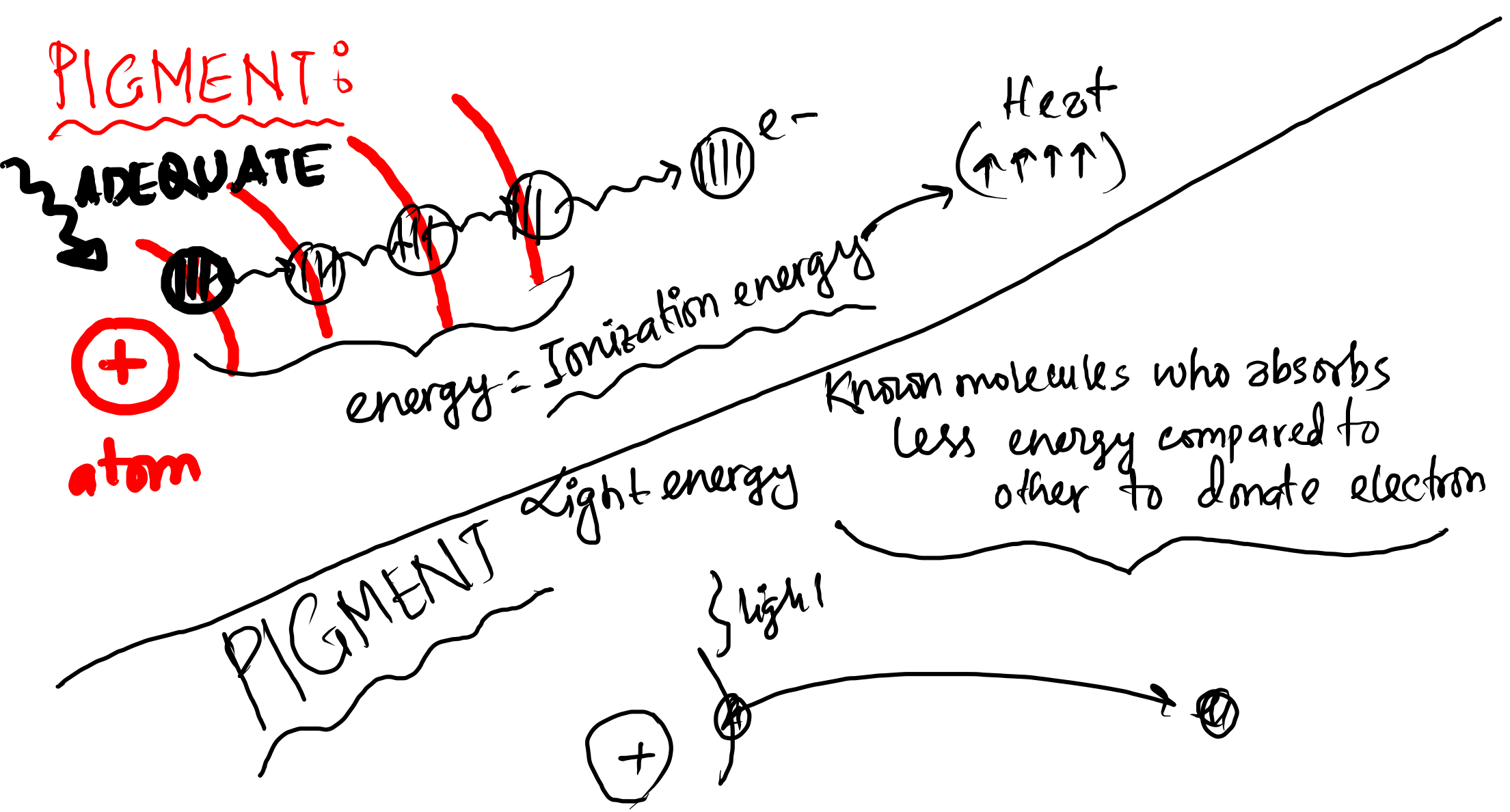


photo - lysis of water

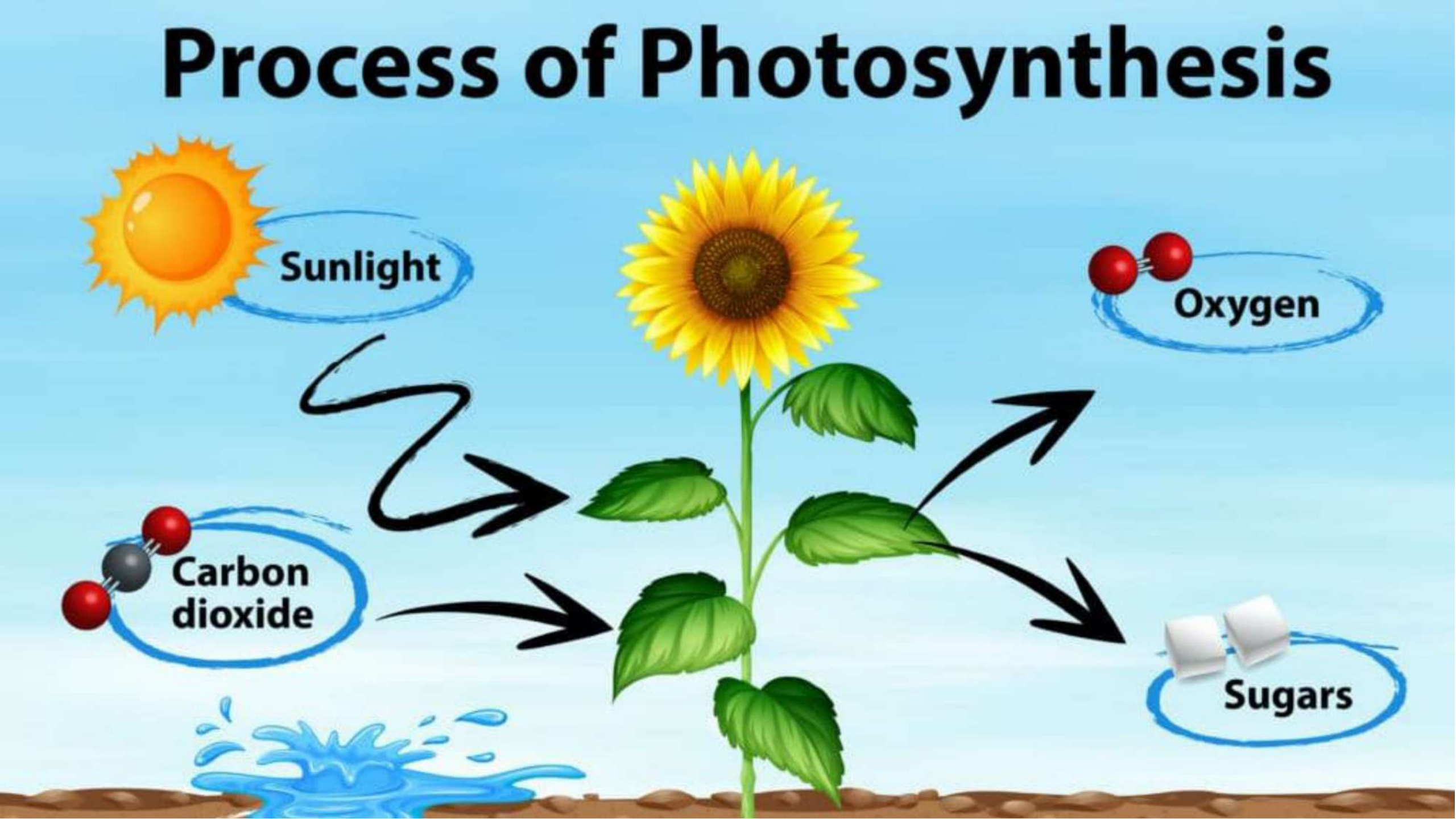

PIGMENT:
ADEQUATE
e-
Heat
energy = Ionization energy
atom
PIGMENT
Light energy
Known molecules who absorbs
less energy compared to
other to donate electron
light

Photosynthesis

- Photolysis of water: Breakdown of water (H_2O) into oxygen (O_2), Hydrogen ion or proton ($2H^+$) and electron (e^-) in presence of sunlight is called photolysis of water.

$$\underset{\text{Carbon-di-oxide}}{6CO_2} + \underset{\text{Water}}{12H_2O} \xrightarrow[\text{Chlorophyll}]{\text{light}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} + \underset{\text{Water}}{6H_2O}$$

Process of Photosynthesis



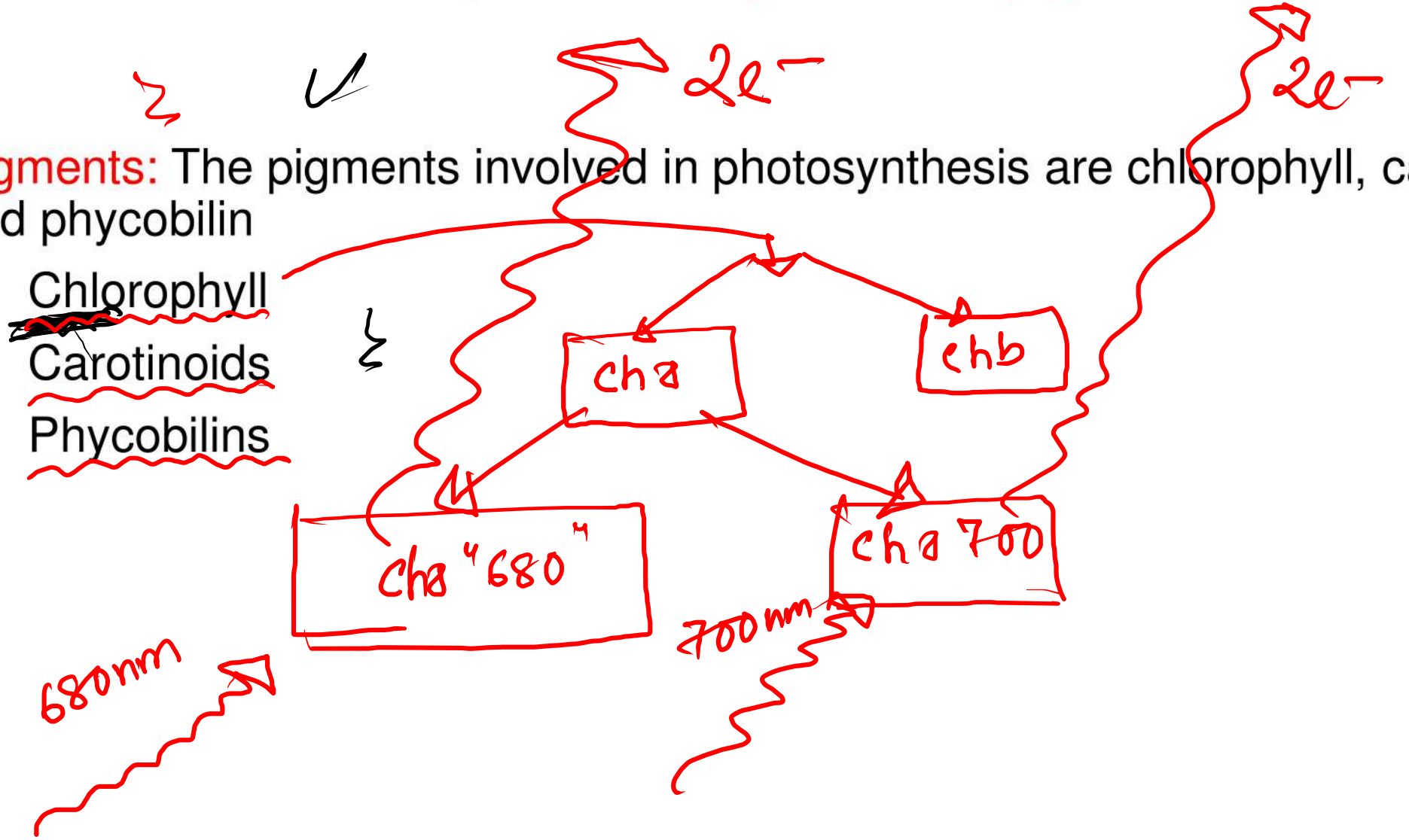
Photosynthetic organs and pigments

In plants, chloroplasts are found in parts of the body that are green. Green algae, thalloid bryophytes such as *Riccia*, *Marchantia* have chloroplasts all over their entire body. However chloroplasts are present in the tender shoots and leaves of higher class plants. Chloroplasts are mostly available in leaves, so green leaves are considered to be the organs of photosynthesis.

Photosynthetic organs and pigments

Pigments: The pigments involved in photosynthesis are chlorophyll, carotenoids and phycobilin

1. Chlorophyll
2. Carotinoids
3. Phycobilins



PHOTOSYSTEM

LIGHT DEPENDENT PHASE

photon → ATP

photon

chα (680/700)

TEAM B / REACTION CENTRE

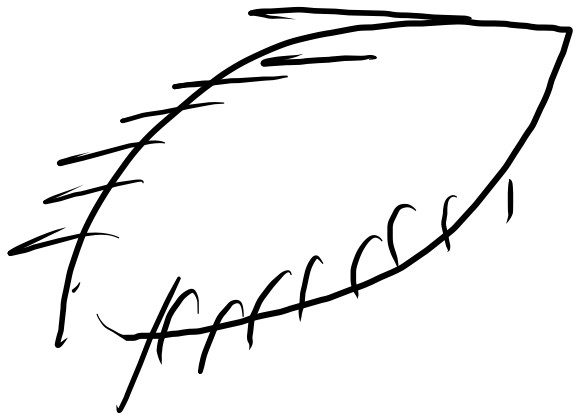
energy/photon

LIGHT ABSORPTION TEAM

ch b

Cartoene

Phycobillins



2e⁻

electron transport chain

ETC

Fd

PQ

cyt

PC

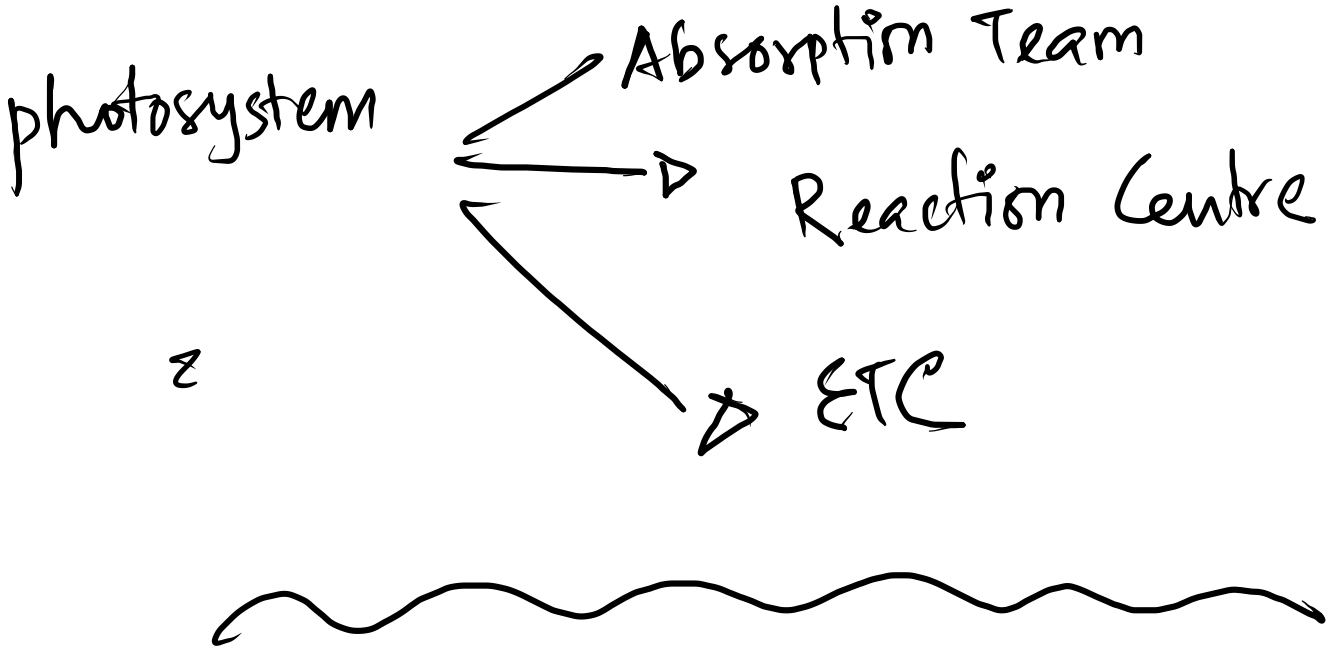
ATP

Fd = Ferridoxin

PQ = Plasto Quinone

cyt = cytochrome

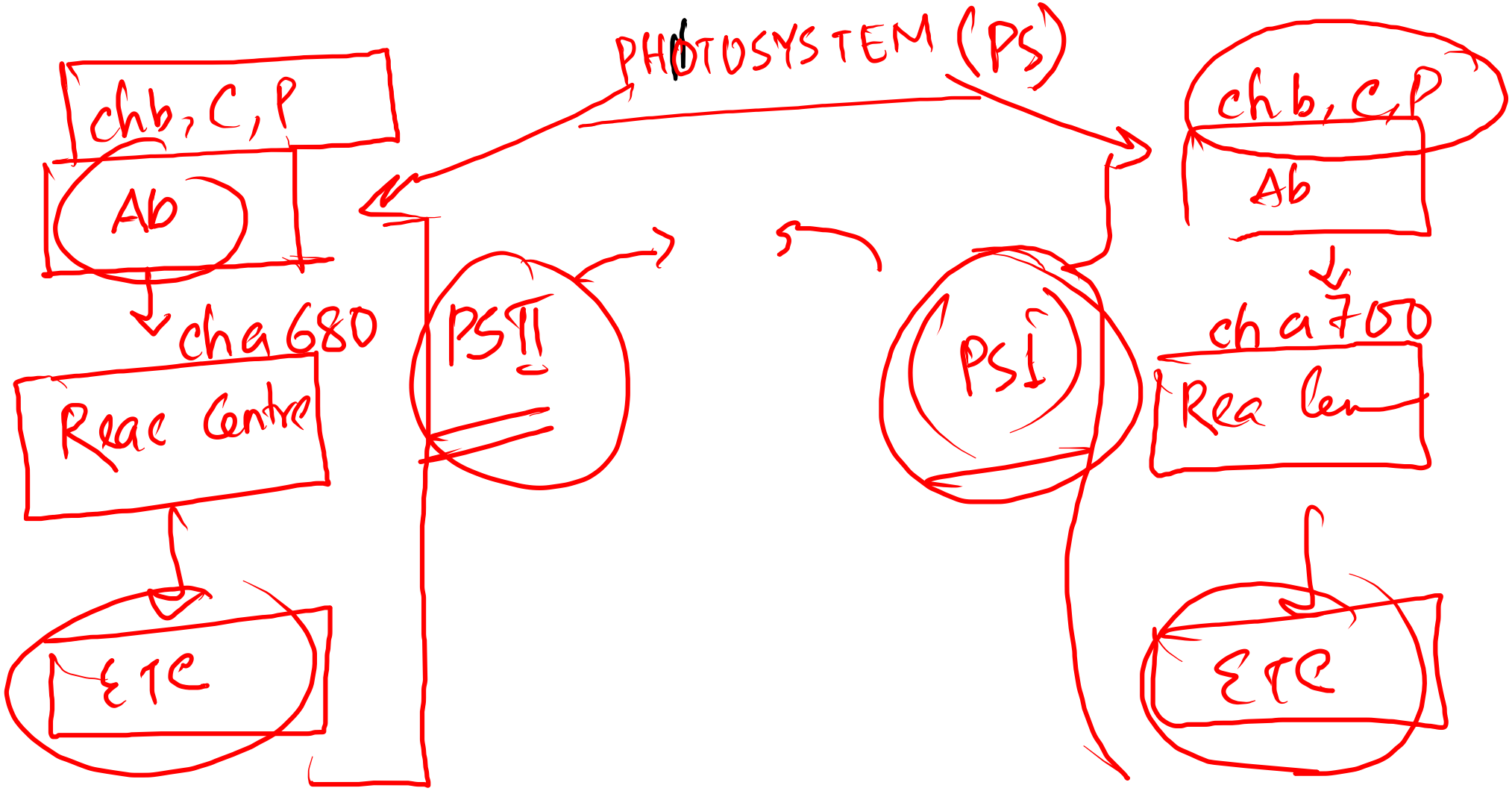
PC = Plastocyanine

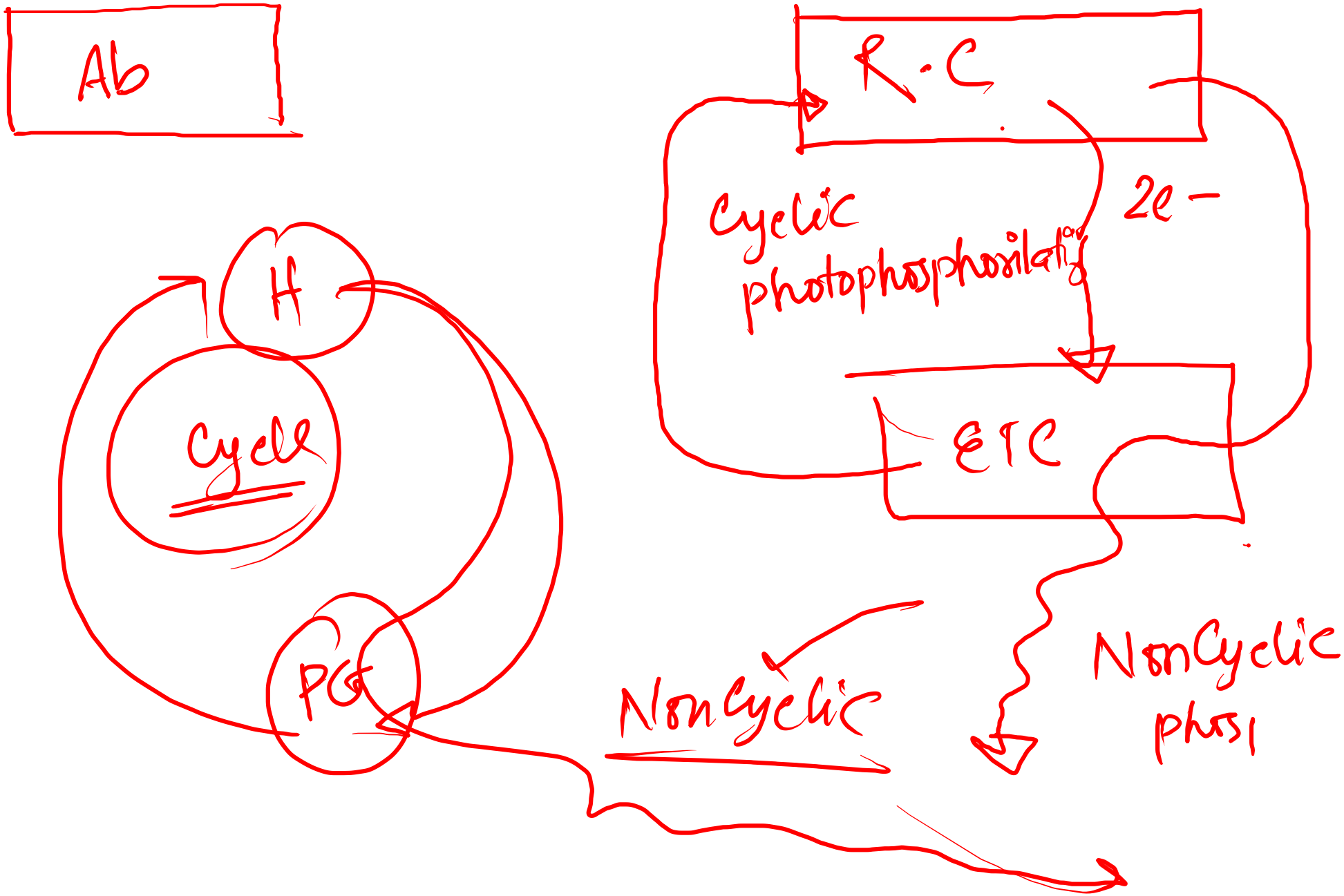

photosystem
Absorption Team
Reaction Centre
ETC

Chemical reaction of light

- **Photosystem:** Chlorophyll and its relevant electron acceptors together exist as a 'unit'. This unit is called photosystem. Photosystems are present on thylakoid membrane and they contain up to 400 chlorophyll molecules. There are two types of photosystem on thylakoid membrane.

- According to continuity of invention of photosystem-I and photosystem- II, PS-I and PS-II is named


PHOTOSYSTEM (PS)
chb, C, P
Ab
cha 680
Reac Centre
ETC
PSII
PSI
chb, C, P
Ab
cha 700
Rea Cen
ETC


Ab
R.C
Cyclic photophosphorilation
2e-
ETC
H
Cycle
PG
NonCyclic
NonCyclic phosl

NON CYCLIC PHOTOPHORILATION

= Absorption Region

= Reaction Centre

H_2O → $2H^+ + 2e^- + [O]$

photon

2e⁻

PS II / Cha 680

Cha 680

PQ II

2e⁻

eT

PC

2e⁻

cyt III

2e⁻

ADP

ATP

stopped

2e⁻

Fd

Cha 700

PS I

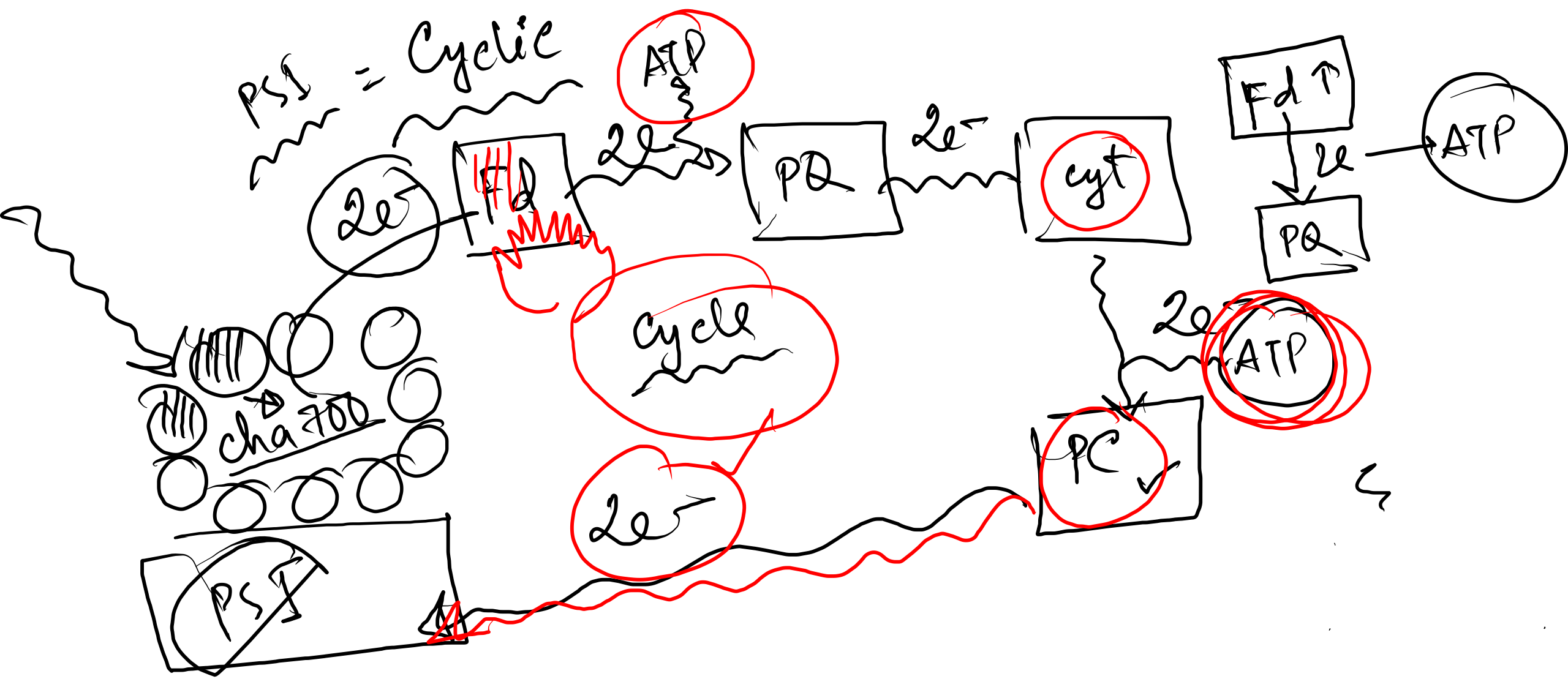
$Cha680 - 2e = (Cha680)^{2+}$

2e⁻

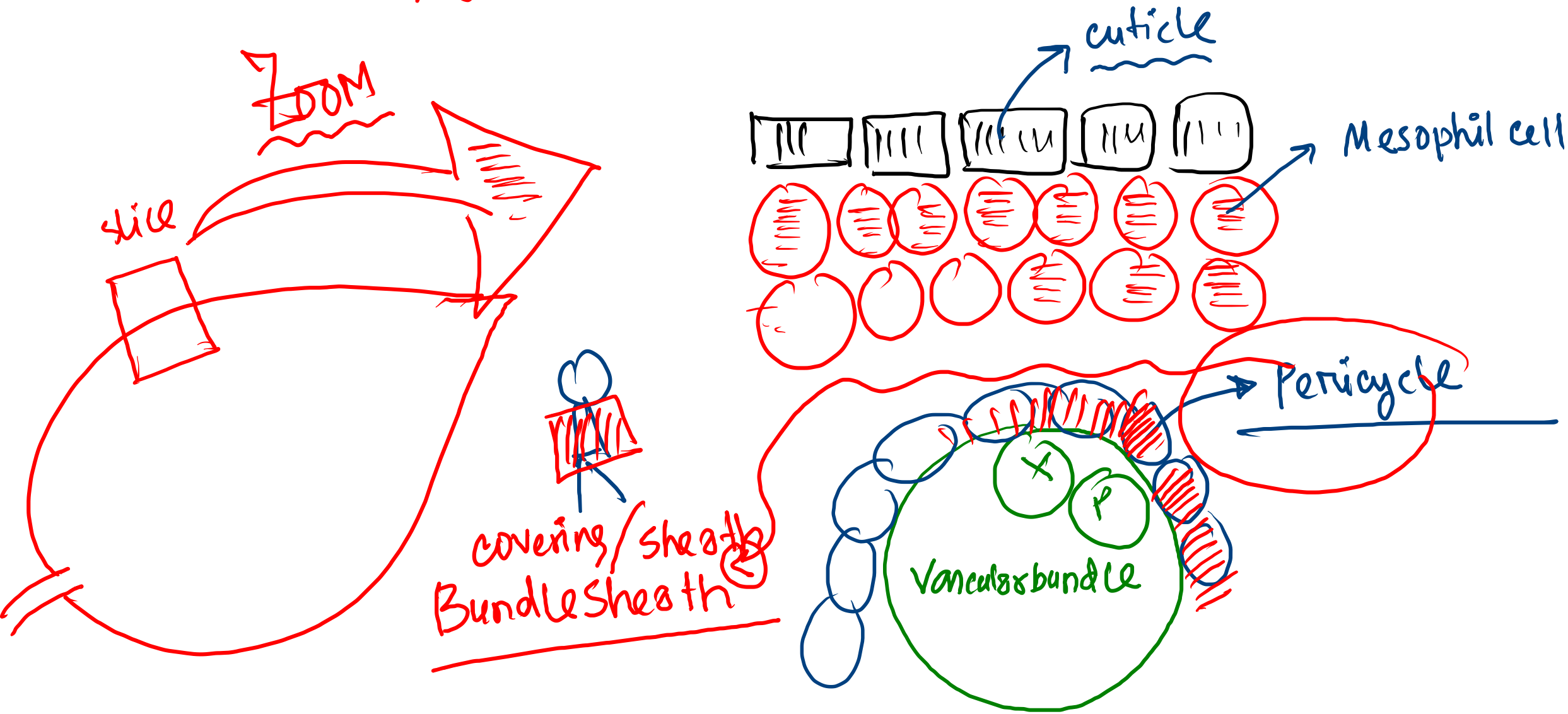
$Cha680^{2+} + 2e^- = Cha680$

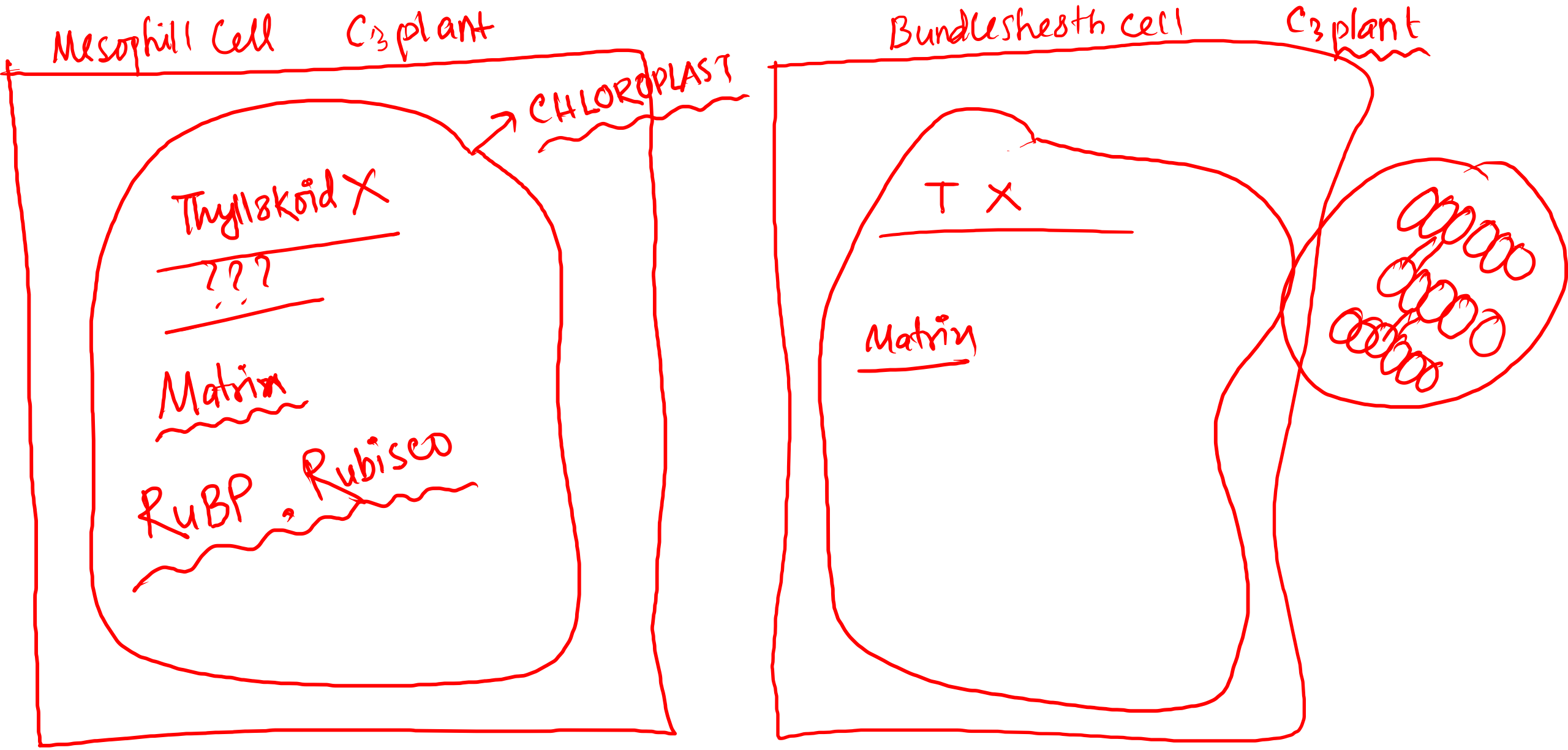
$NADP^+ + 2H^+$

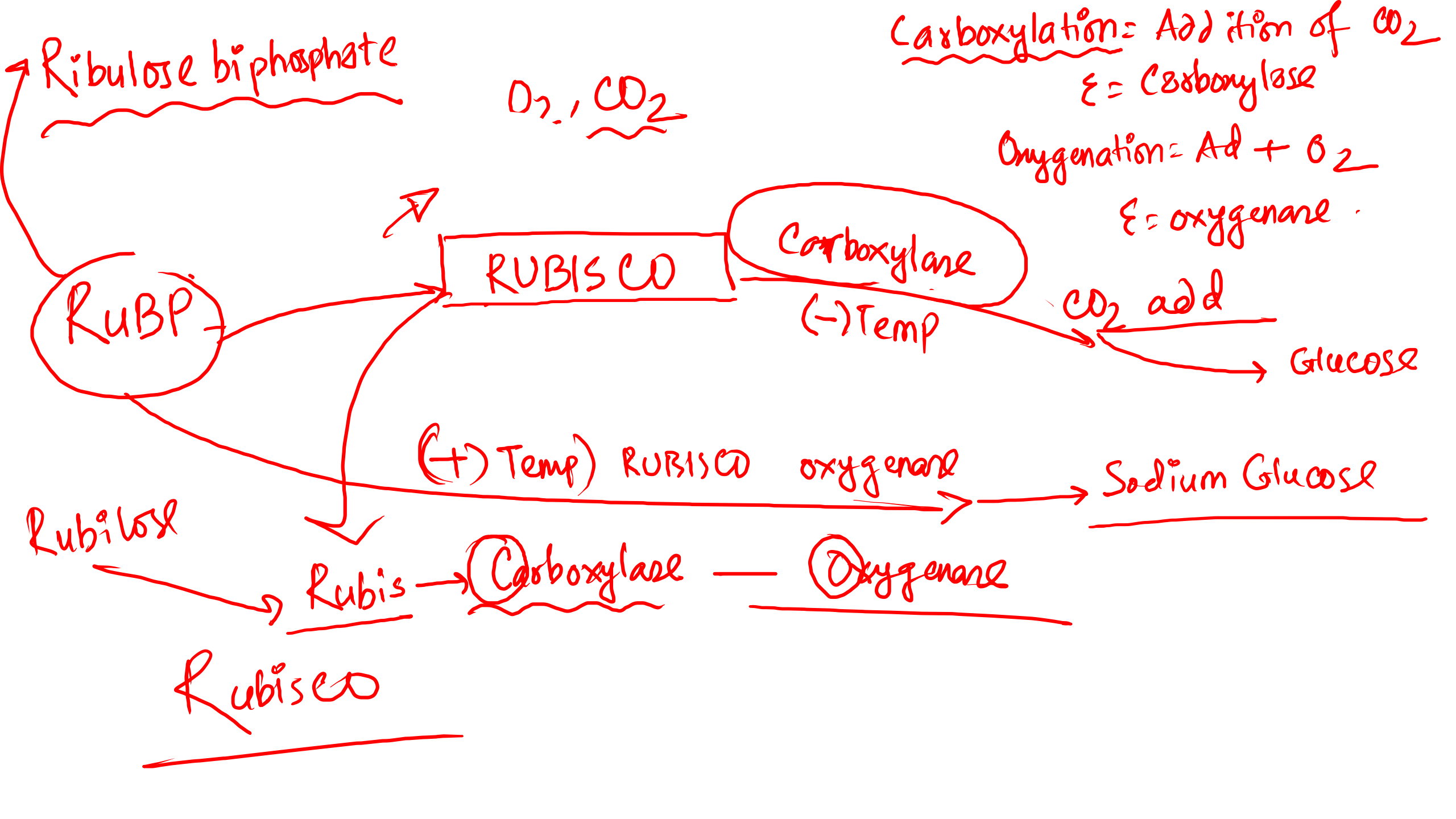
$\rightarrow NADPH_2$

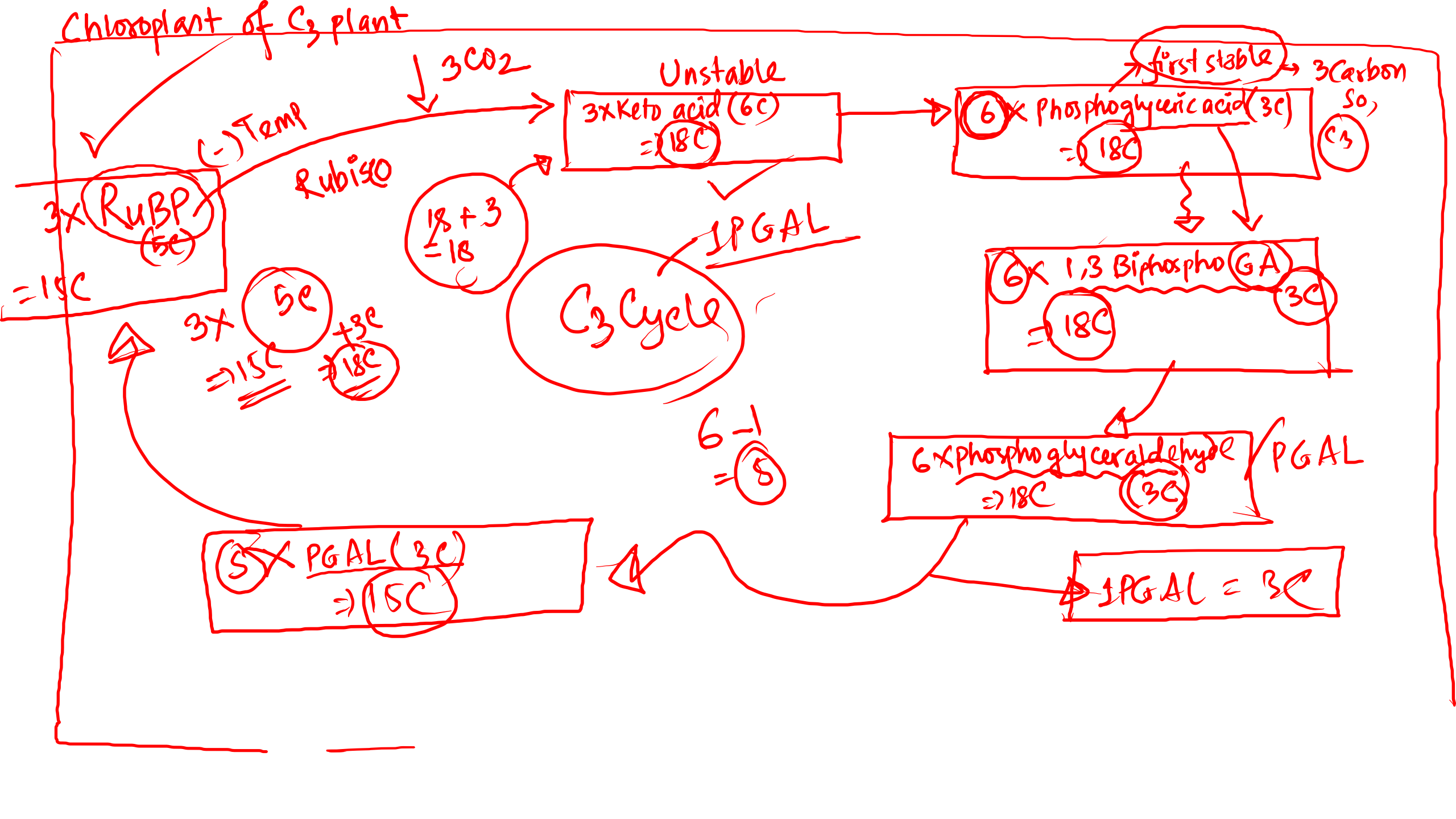

PSI = Cyclic
ATP
2e⁻
Fd
2e⁻
PQ
2e⁻
cyt
Fd↑
2e⁻
ATP
PQ
Cycle
2e⁻
2e⁻
ATP
PC
PSI

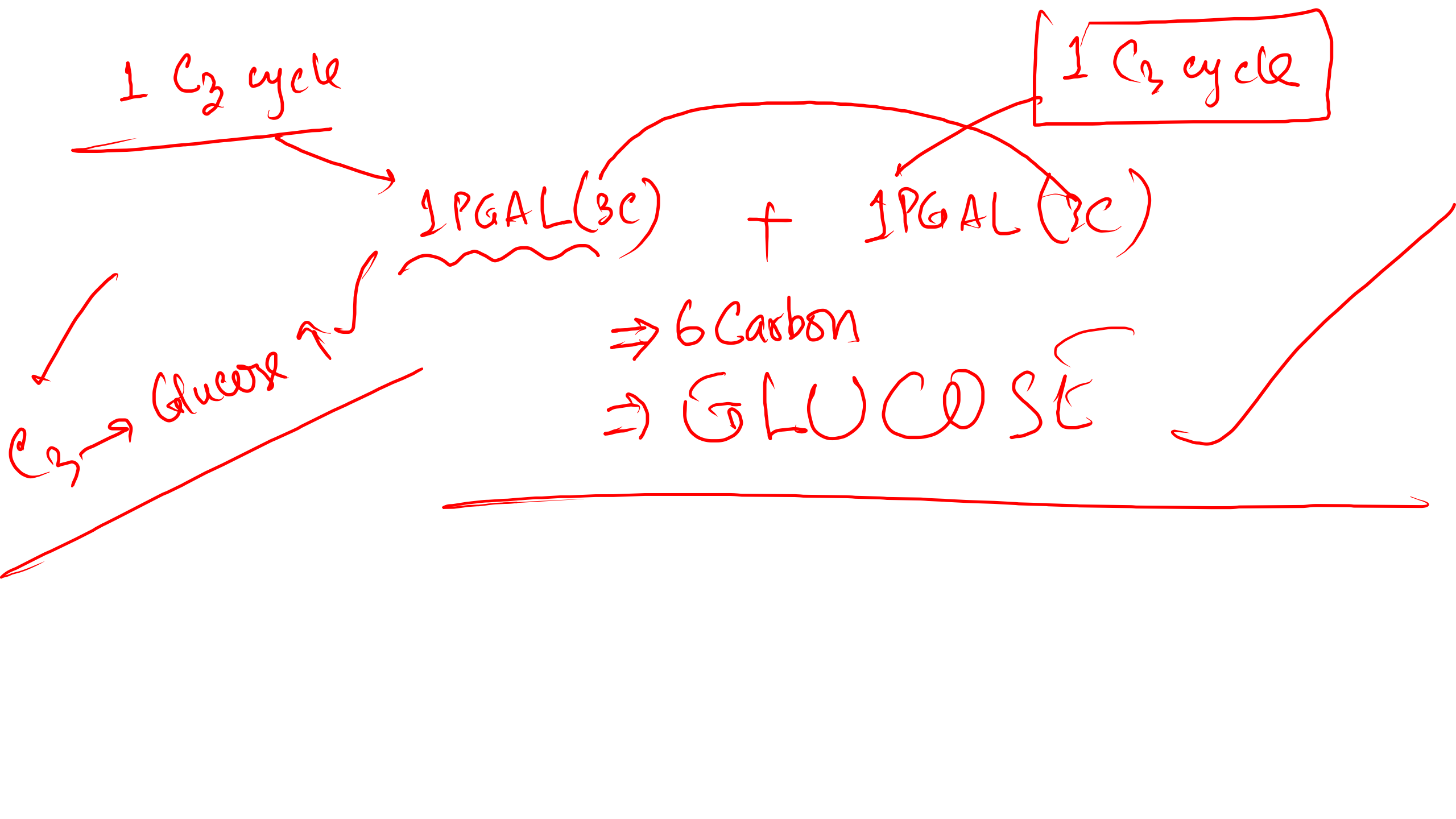
LIGHT INDEPENDENT REACTION / DARK PHASE




Mesophill Cell
C3 plant
CHLOROPLAST
Thylakoid X
???
Matrix
RuBP
Rubisco
Bundlesheath cell
C3 plant
T X
Matrix


Ribulose biphosphate
O_2, CO_2
Carboxylation = Addition of CO_2
E = Carboxylase
Oxygenation = Add + O_2
E = oxygenase
RuBP
RUBISCO
Carboxylase
(-) Temp
CO_2 add
Glucose
(+) Temp) RUBISCO oxygenase
Sodium Glucose
Rubilose
Rubis
Carboxylase — Oxygenase
Rubisco


Chloroplast of C3 plant
3CO2
(-)Temp
Rubisco
3x RuBP (5C)
=15C
Unstable
3x Keto acid (6C)
=18C
18+3
=18
C3 Cycle
1PGAL
first stable
3Carbon
So,
C3
6x Phosphoglyceric acid (3C)
=18C
6x 1,3 Biphospho GA
3C
=18C
6x phosphoglyceraldehyde
=18C
3C
PGAL
6-1
=5
5x PGAL (3C)
=15C
3x 5C
=15C
+3C
=18C
1PGAL = 3C


1 C_3 cycle
1 C_3 cycle
1PGAL(3C) + 1PGAL(3C)
C_3 → Glucose
⇒ 6 Carbon
⇒ GLUCOSE

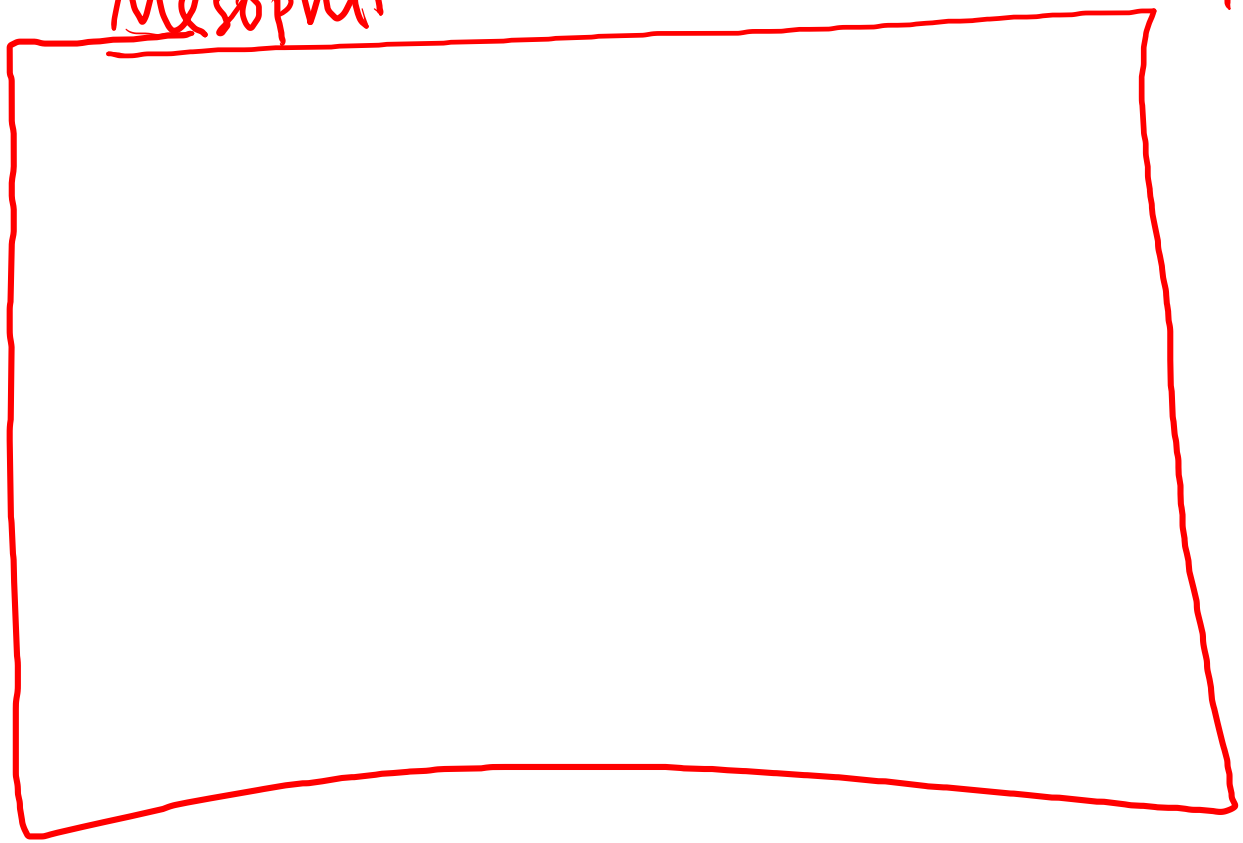
C_4 cycle

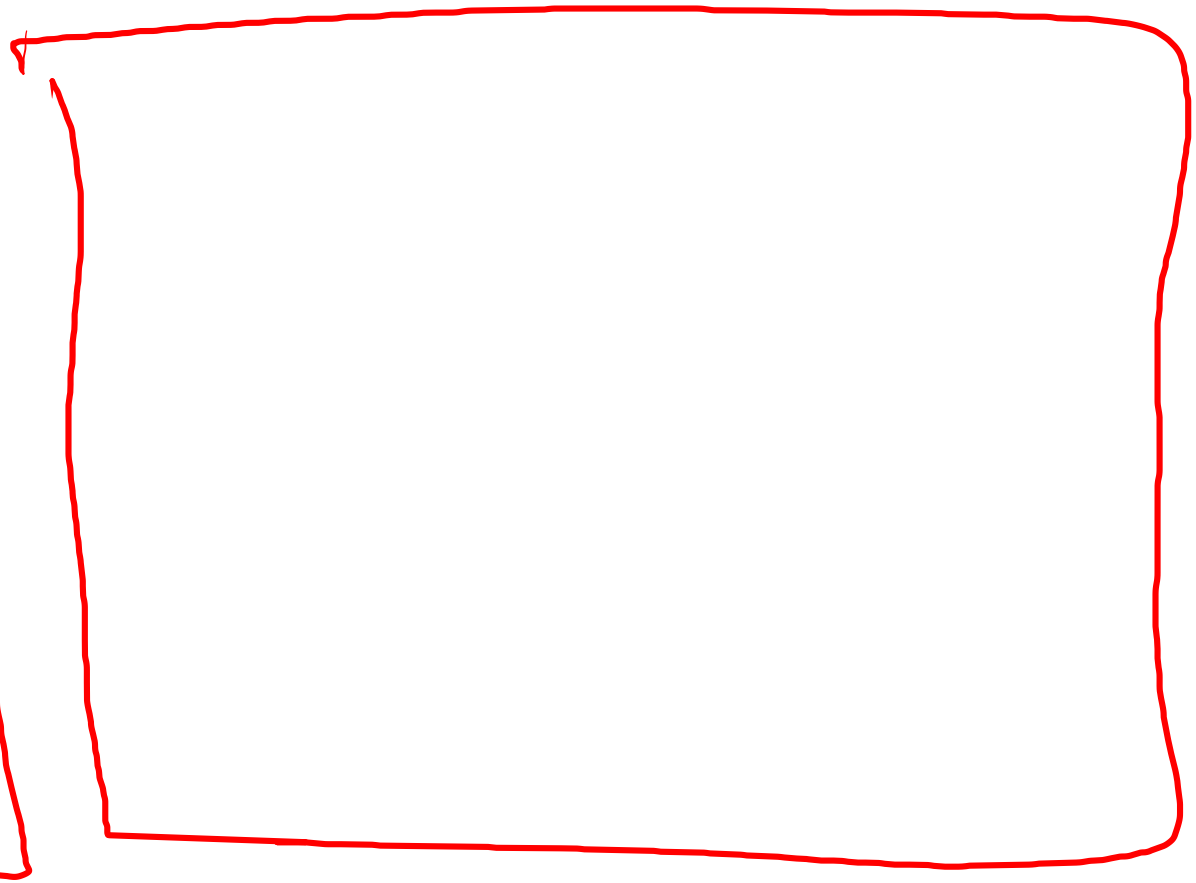
C_3 — diAd : → winter

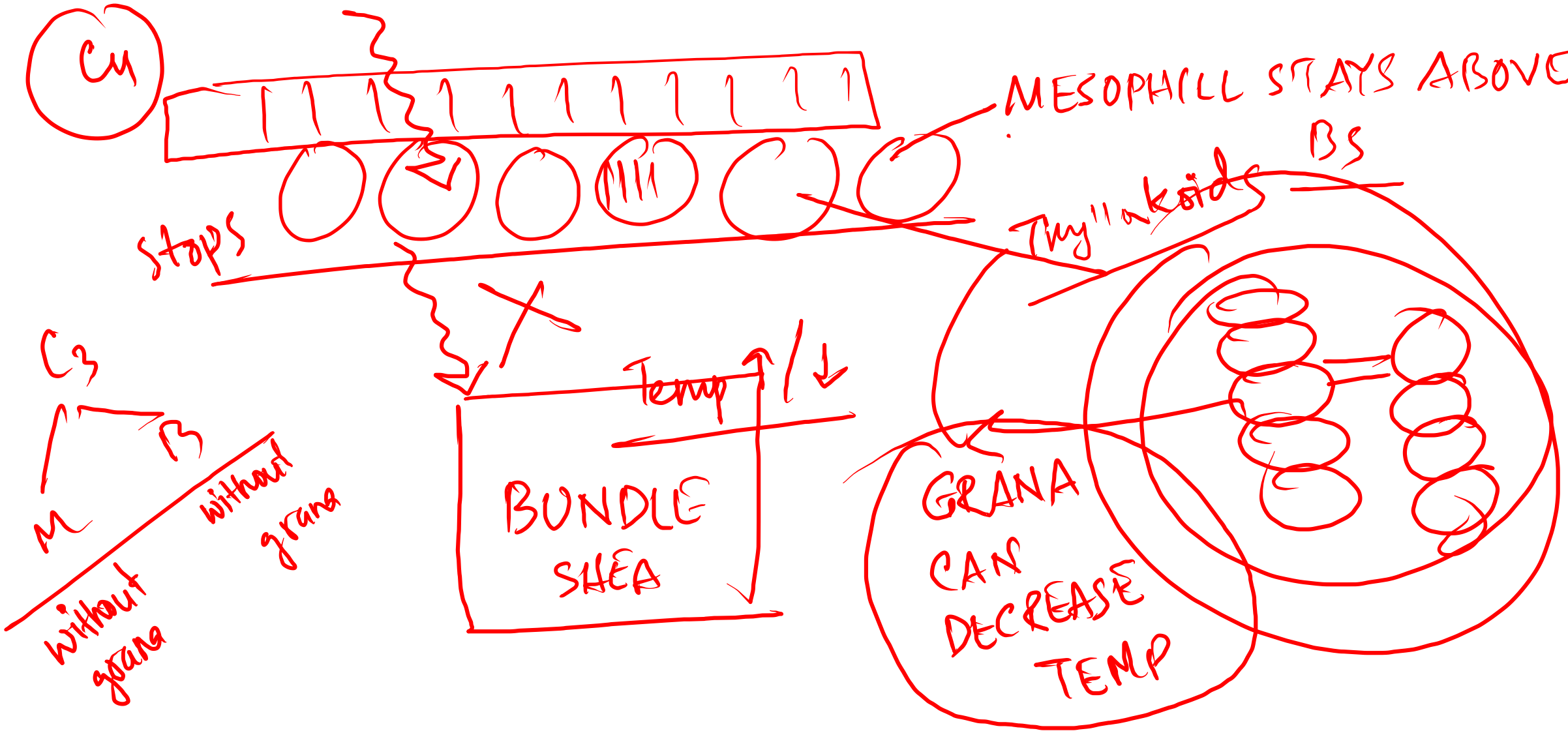
↑Temp → RUBP ——— Glucose

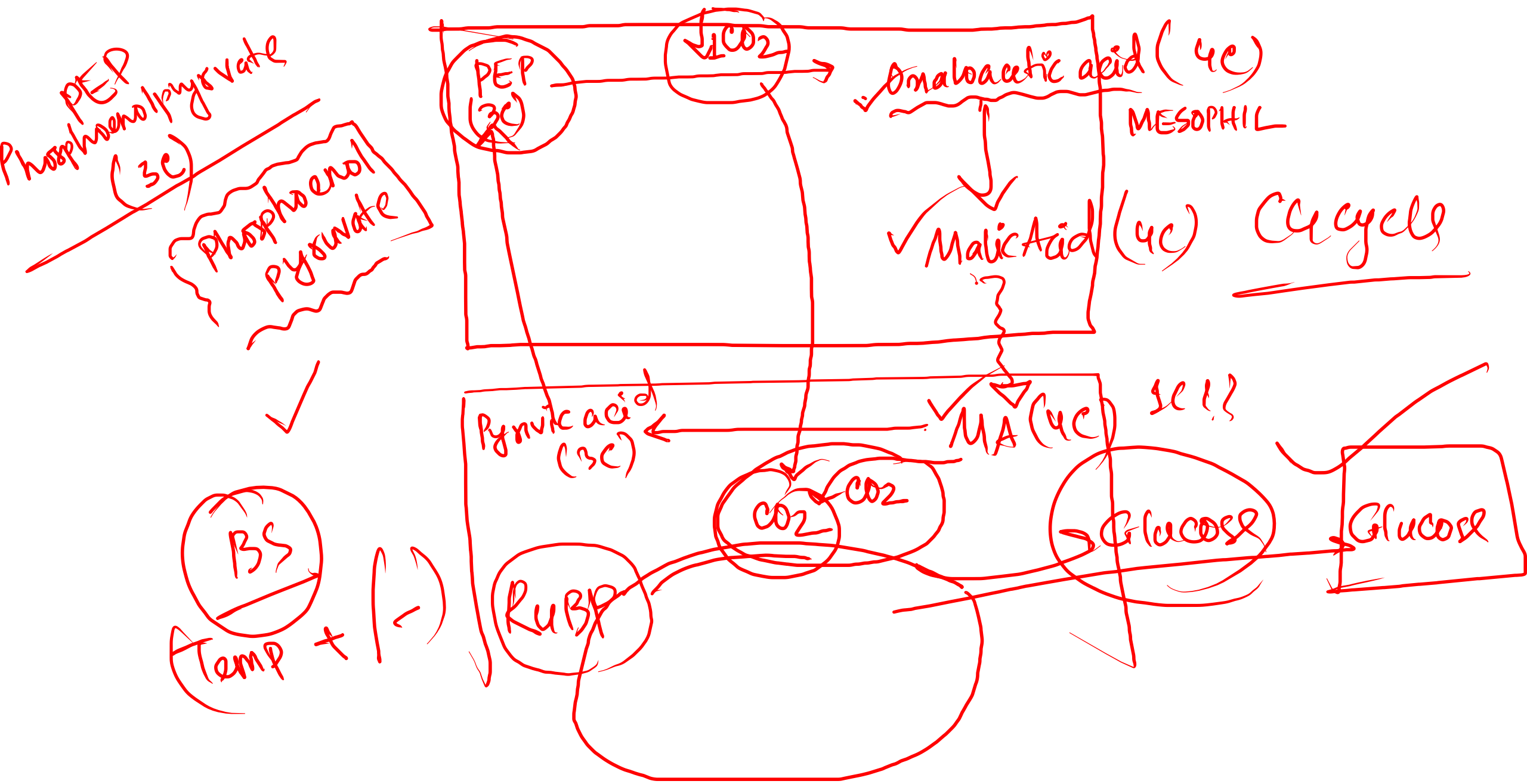
C_4 Adaptations ???

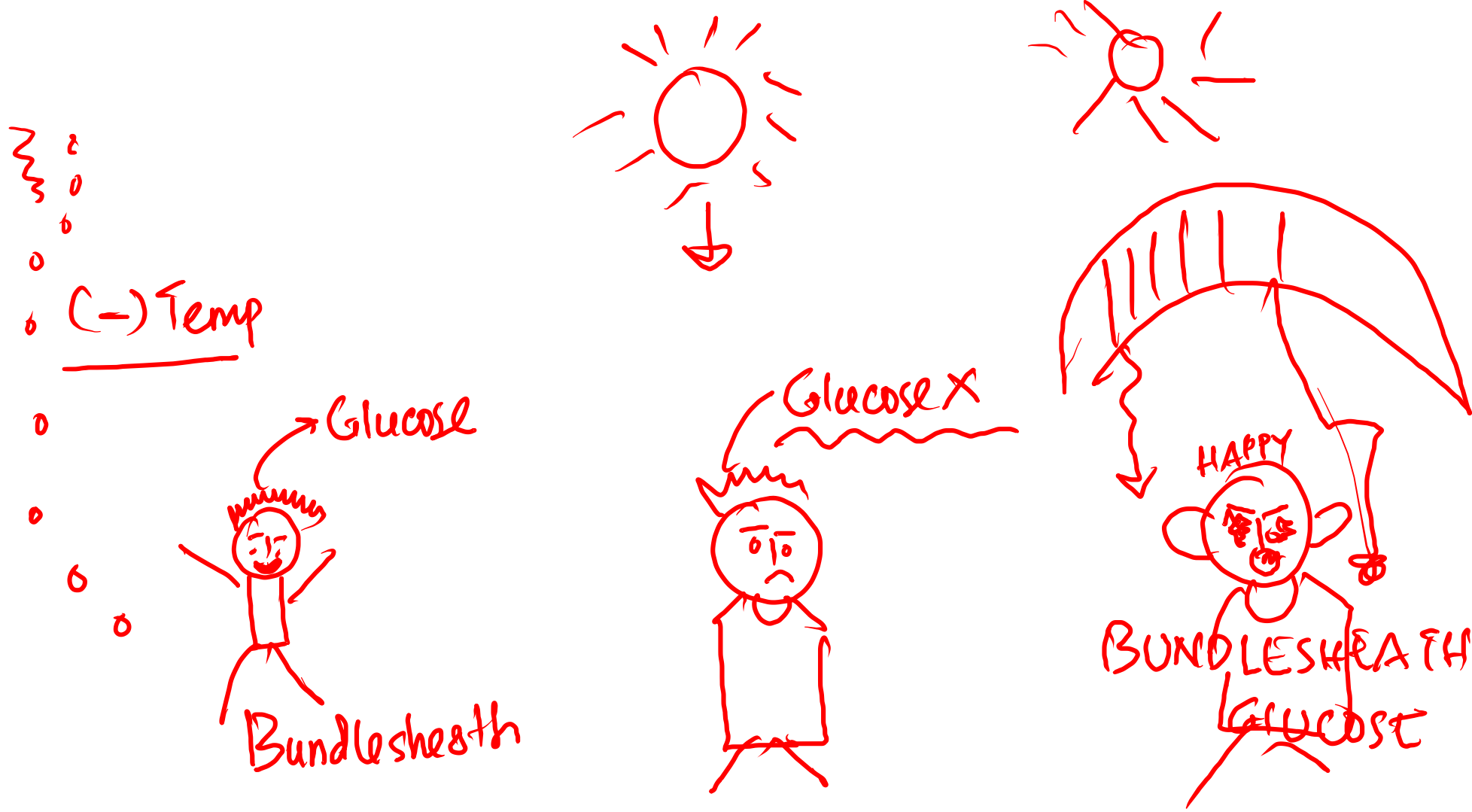
Mesophyll

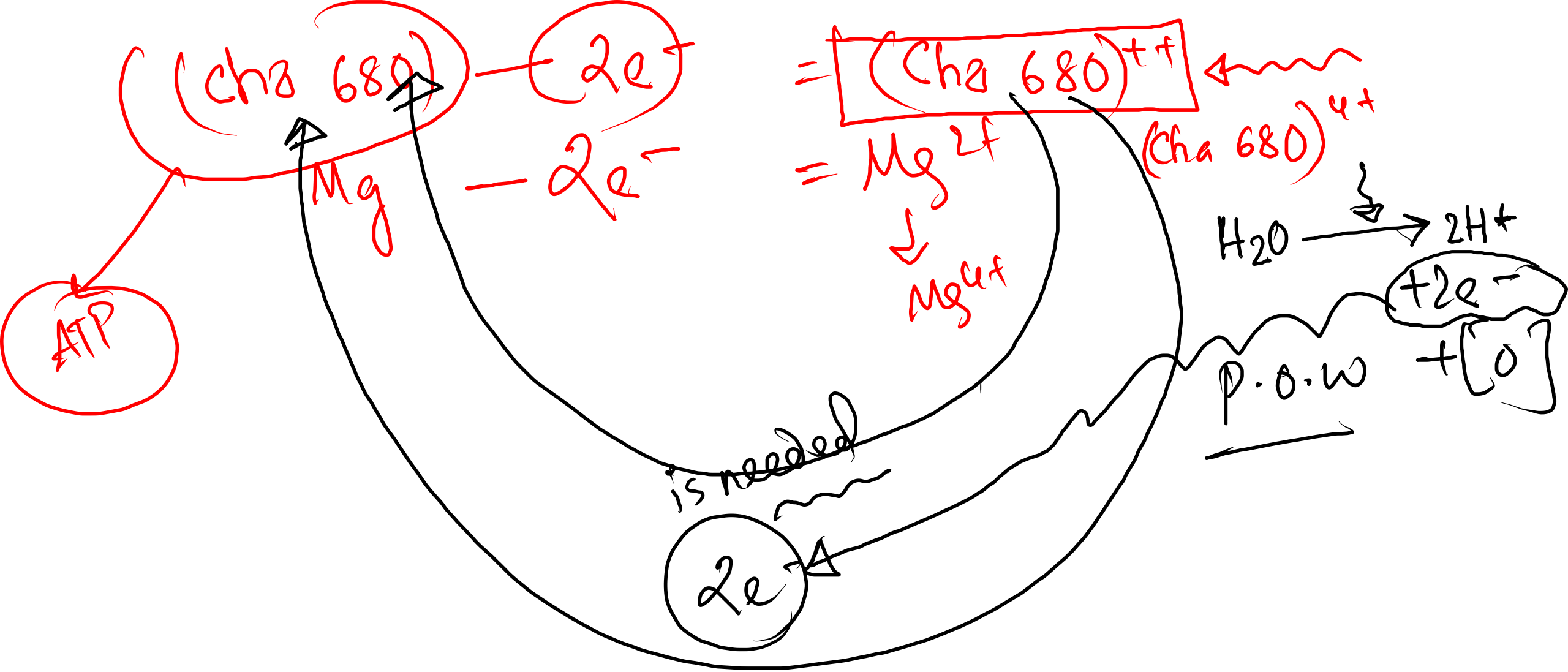


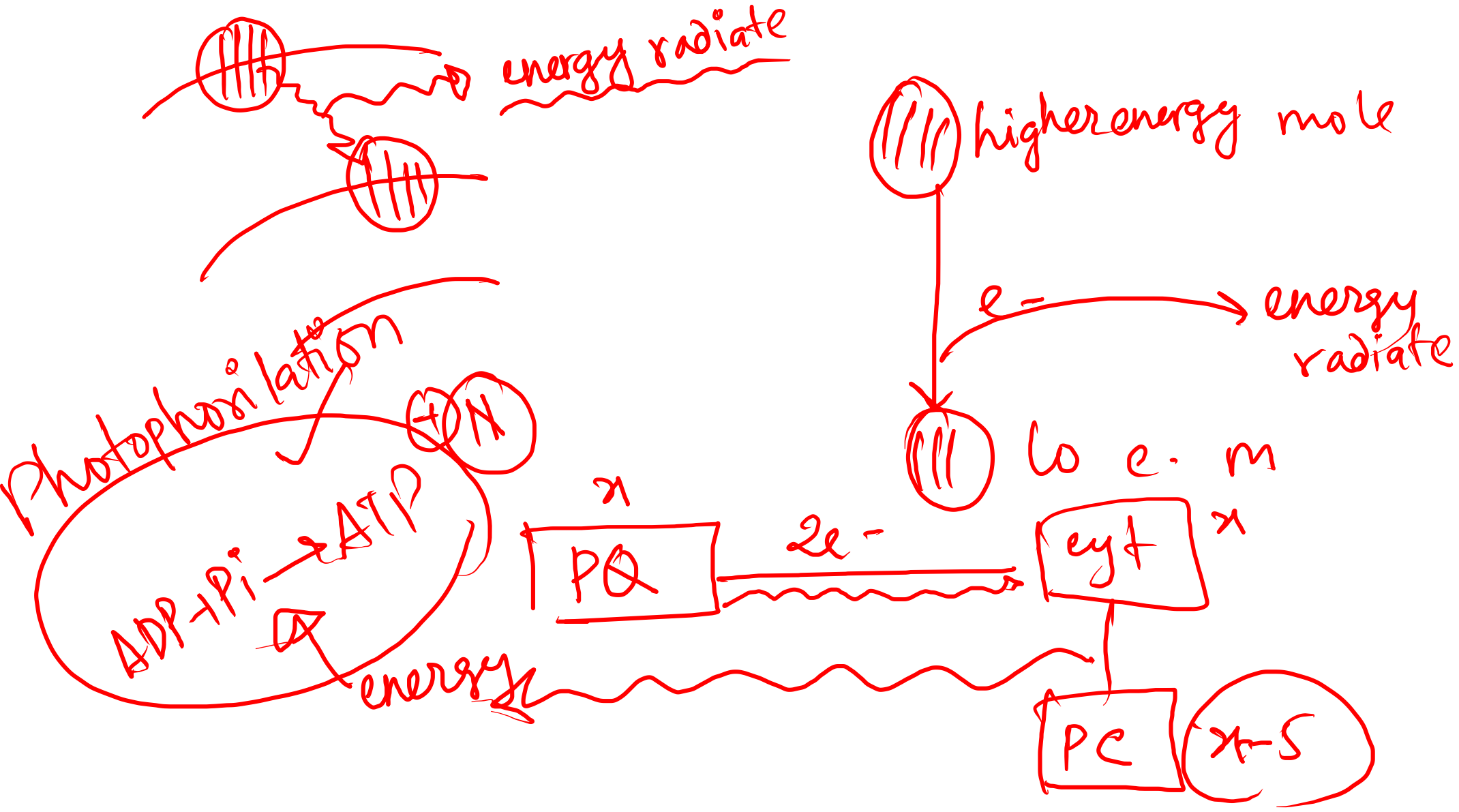



C4
MESOPHILL STAYS ABOVE
BS
stops
C3
B
without grana
M
without grana
Temp
BUNDLE SHEA
GRANA CAN DECREASE TEMP


PEP
Phosphoenolpyruvate
(3C)
Phosphenol pyruvate
PEP (3C)
CO_2
Oxaloacetic acid (4C)
MESOPHIL
Malic Acid (4C)
C4 cycle
Pyruvic acid (3C)
MA (4C)
1C !?
BS
Temp + (-)
CO_2
CO_2
RuBP
Glucose
Glucose


(-) Temp
Glucose
Bundlesheath
Glucose X
HAPPY
BUNDLESHEATH
GLUCOSE


(Chl 680)
2e⁻
=
(Chl 680)⁺⁺
Mg
2e⁻
= Mg²⁺
Mg⁴⁺
(Chl 680)⁴⁺
ATP
H2O
2H+
+2e⁻
+ [O]
P.O.W
is needed
2e⁻


energy radiate
higher energy mole
e-
energy radiate
Photophosphorylation
+N
ADP+Pi → ATP
energy
lo e. m
x
PQ
2e-
eyt
x
PC
x-5

Electron Transport System

(1) Phaeophytin (Ph): A transformed chlorophyll-a molecule. It creates a connection to the next carrier plastoquinone.

(2) Plastoquinone (PQ): Very small movable (mobile) lipid which can move freely in the thylakoid membrane.

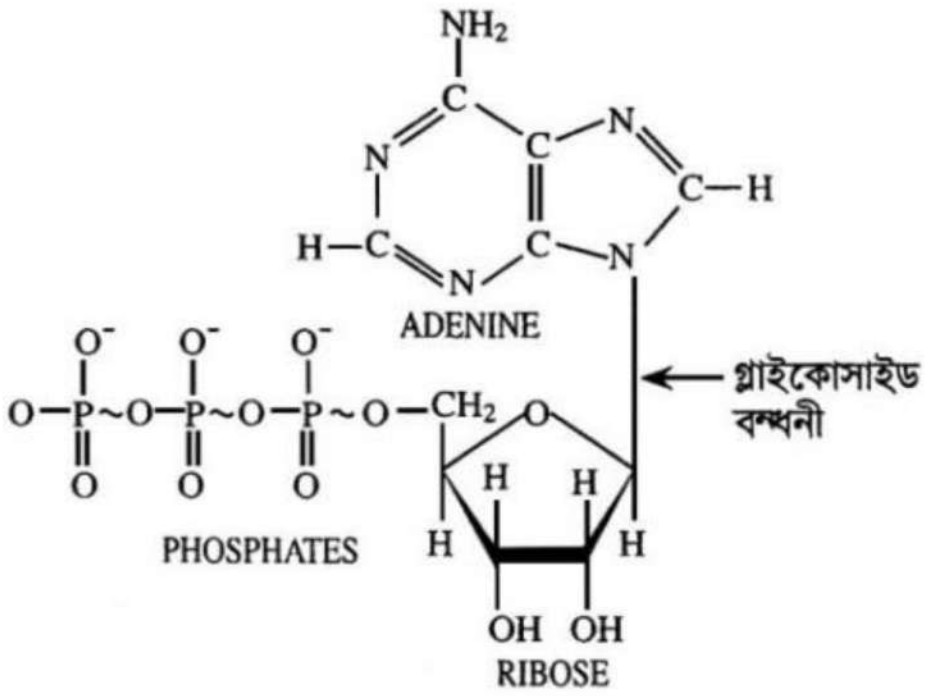
(3) Cytochrome (Cyt): Cytochrome is a ferrous heme protein group.

(4) Plastocyanin (PC): Very mobile small membrane protein. It can move freely in thylakoid chamber.

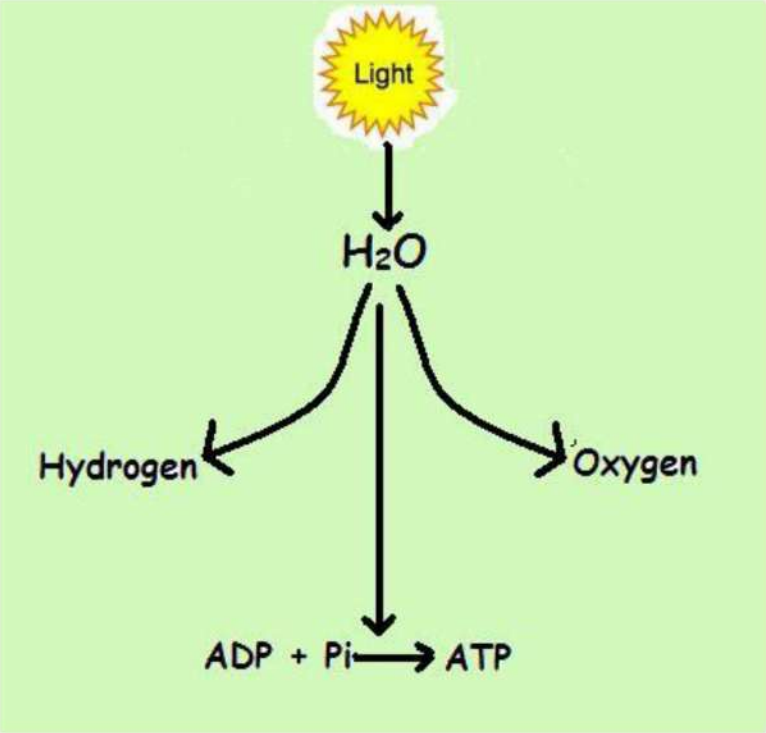
(5) Ferredoxin (Fd): This is an iron-sulfur (Fe-S) protein. Its iron accepts and donates the electron.

(6) NADP reductase: This is actually a flavoprotein and bound co-enzyme FAD (Flavin adenine dinucleotide).

ATP is called biological coin or energy coin



চিত্র : ATP- এর গঠন



Water supply in photosynthesis: In higher class plants, water is an essential element for photosynthesis. The main places where photosynthesis occurs are the chloroplasts of mesophyll tissue of the leaves. Therefore, there must be a continued supply of water to mesophyll cells.

Entrance of CO_2 in mesophyll tissue of the leaf: CO_2 is the main ingredient in the process of photosynthesis because the main raw material of sugar is CO_2; green plants take it from the air. 0.035% CO_2 is present in the atmosphere.

Poll Question 01

Among these which is not a protein inspite of being in the ETC?

a. Plastocyanin
b. Plastoquinone
c. Ferredoxin
d. Cytochrome

Mechanism of photosynthesis

In 1905, British physiologist Blackman divided photosynthesis into two parts-

(i) light-dependent stage

(ii) light-independent stage.

Light dependent reactions

Light dependent reactions: ATP and NADPH + H^+ are formed.
This stage occurs in thylakoid membrane. Light energy is converted into chemical energy and transmitted in ATP and NADPH + H^+ in this stage. Light is essential for this stage.

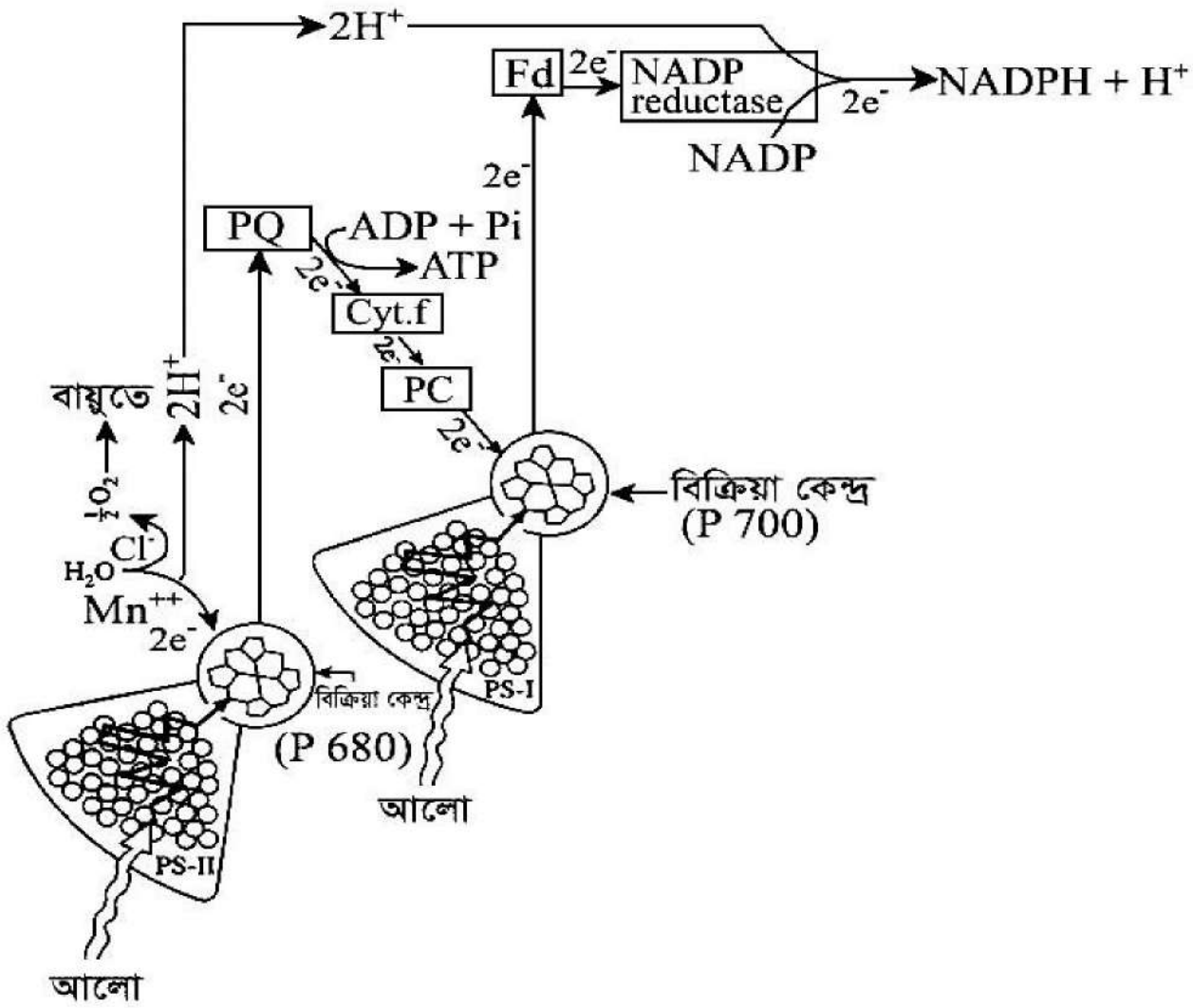
Photophosphorylation

The combination of phosphate to another compound is called phosphorylation and if phosphorylation is carried out using light energy, it is called photophosphorylation. In photosynthesis, the process that uses light energy to produce ATP, is called photophosphorylation.

Photophosphorylation can be of two types-

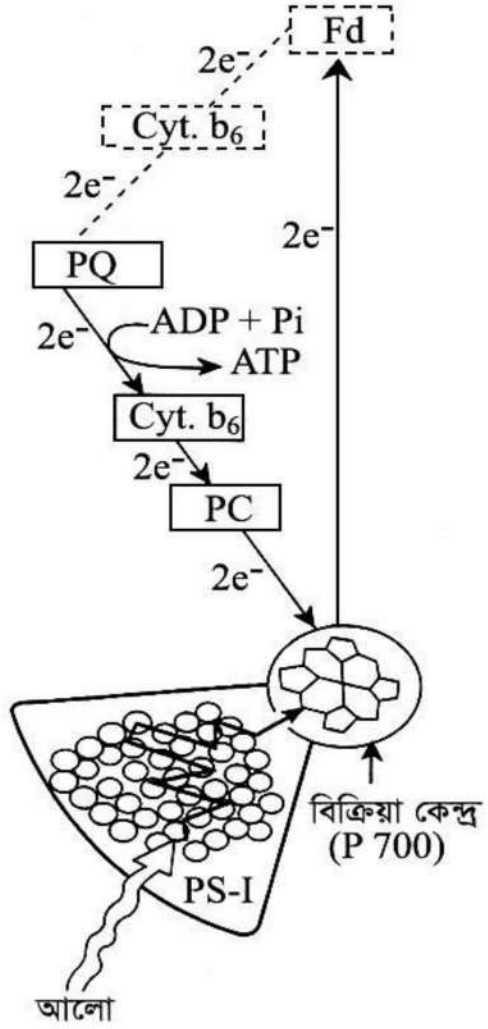
cyclic and non-cyclic

Non-cyclic photophosphorylation



Non-cyclic photophosphorylation

Cyclic photophosphorylation



Cyclic photophosphorylation

Light independent reactions

- **Light independent reactions:** The carbohydrate production or carbon reduction process.
- ATP and NADPH + H^+ from light dependent reactions are used to produce carbohydrate from CO_2. In this stage, CO_2 is reduced to produce carbohydrate, so it is called carbon reduction stage. It does not require light directly. So it is called light independent stage or dark stage.

Light independent reactions

In this stage, reactions take place in stroma of chloroplasts. There are three ways to convert CO_2 into carbohydrates by chemical reactions. They are:

(1) Calvin cycle,

(2) Hatch and slack cycle and

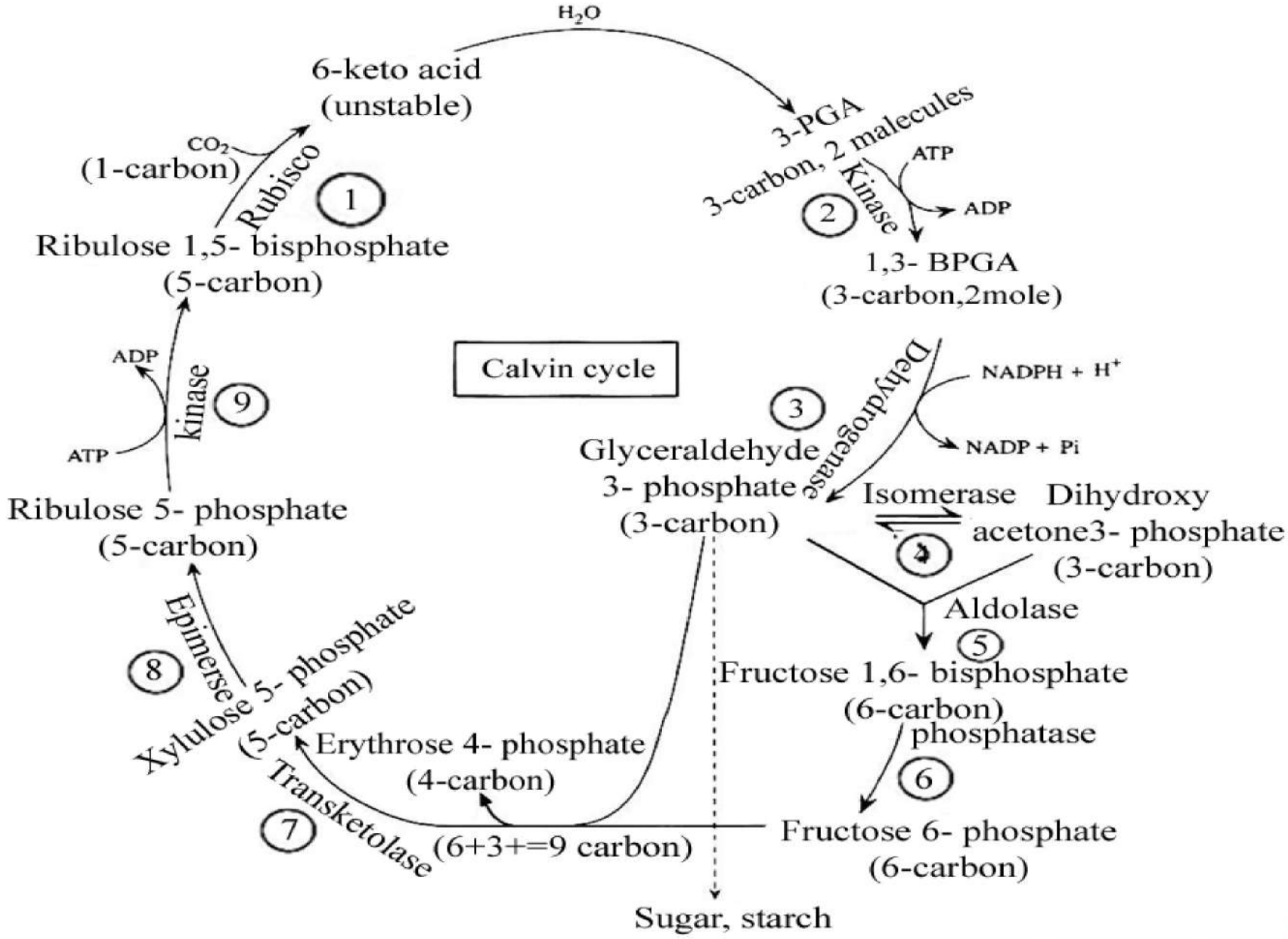
(3) CAM process

Calvin cycle or C_3 cycle

- ✓ Calvin (Melvin Calvin, 1911-1997, Benson & Bassham) and his associates at the University of California in 1947-1949, discovered a cyclical process of carbon reduction in unicellular algae *Chlorella* by using radioactive carbon isotope (^{14}C isotope) in tracer technique.

- ✓ This process is known as Calvin cycle.

- ✓ Calvin was awarded the Nobel Prize for this in 1961.


Calvin cycle
H_2O
6-keto acid
(unstable)
CO_2
(1-carbon)
Rubisco
1
Ribulose 1,5- bisphosphate
(5-carbon)
3-PGA
3-carbon, 2 malecules
ATP
ADP
Kinase
2
1,3- BPGA
(3-carbon,2mole)
NADPH + H^+
NADP + Pi
Dehydrogenase
3
Glyceraldehyde
3- phosphate
(3-carbon)
Isomerase
4
Dihydroxy
acetone3- phosphate
(3-carbon)
Aldolase
5
Fructose 1,6- bisphosphate
(6-carbon)
phosphatase
6
Fructose 6- phosphate
(6-carbon)
(6+3+=9 carbon)
Transketolase
7
Erythrose 4- phosphate
(4-carbon)
Xylulose 5- phosphate
(5-carbon)
Epimerse
8
ADP
ATP
kinase
9
Ribulose 5- phosphate
(5-carbon)
Sugar, starch

Photorespiration

- If there are high light intensity and temperature in the environment during the C_3 cycle or Calvin cycle in green plants, photorespiration occurs instead of photosynthesis. Photorespiration takes places if CO_2 concentration is less and O_2 concentration is high in chloroplasts.

- Therefore chloroplast, peroxisome and mitochondria are involved in photorespiration. Photorespiration decreases the rate of photosynthesis up to 25% in C_3 plants.

Poll Question 02

What's the first stable component of the Calivin cycle?

a. Ribulose-5-Phosphate

b. Keto acid

c. 3-Phosphoglycericacid

d. Acetyl-Coa

Hatch and slack cycle of C4 Cycle

- ✓ H. P. Kortschak and his colleagues used $^{14}CO_2$ in sugarcane and Y. Karpilov and his colleagues used the same method in maize plants. They discovered that 70-80% of the traced carbon is 4 carbon containing malic acid and aspartic acid.

- ✓ It is also known as dicarboxylic cycle Recently, this pathway is discovered in many plants of 16 families

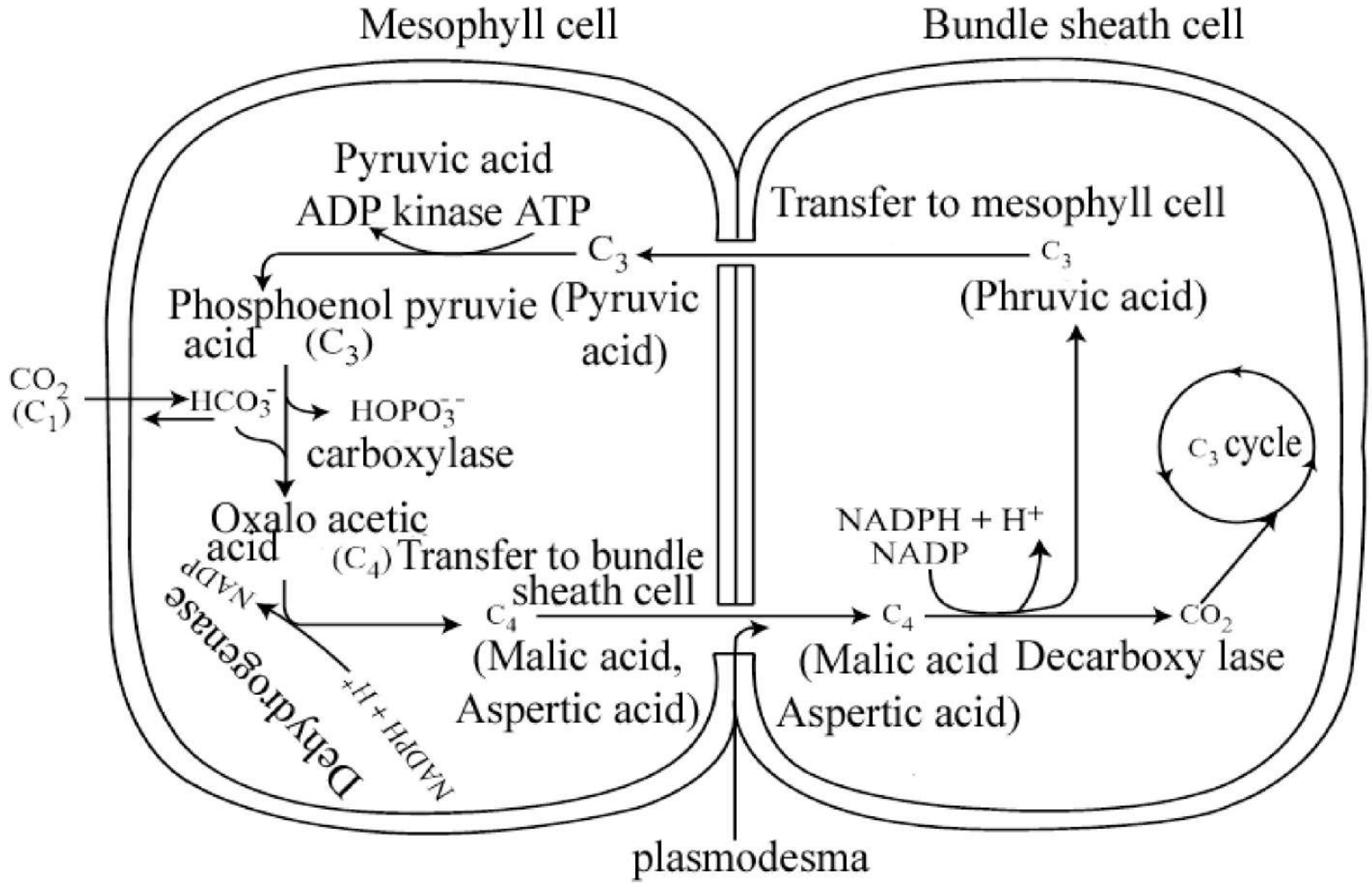


Fig: Hatch and slack cycle

Three types of C_4 pathways are found in plants:

(i) Nature of C_4 acids transferred to bundle sheath cell,
(ii) Nature of C_3 acids transferred to mesophyll cells &
(iii) Types of decarboxylation enzyme in bundle sheath cells.

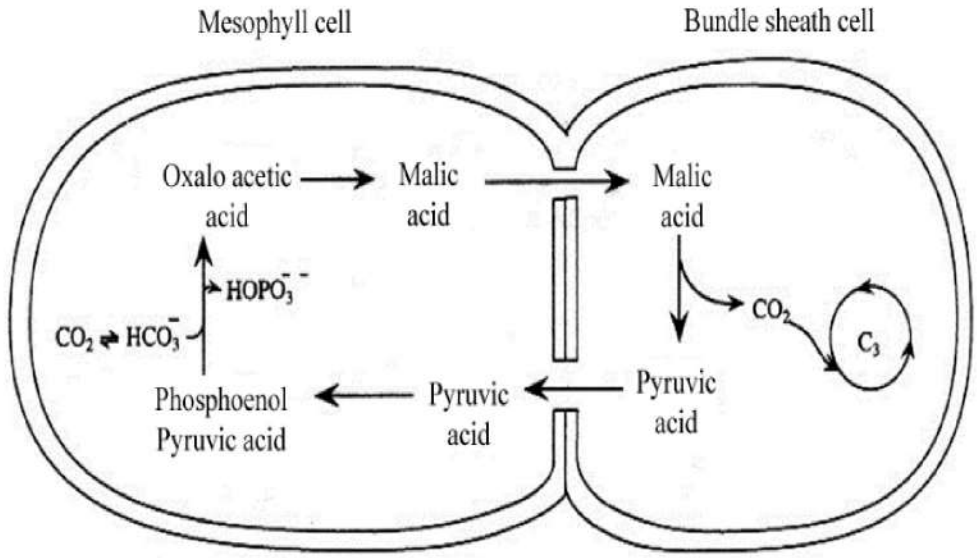


Fig: C_4 Cycle

(a) NADP-malic enzyme type: Effective in maize, sugarcane, sorghum, crab grass etc.
(b) NAD-malic enzyme type: Effective in Millet, Chana etc.
(c) Phosphoenolpyruvate carboxykinase type: Effective in Guinea grass.

Differences between C3 and C4 plant

Traits	C_3 plant	C_4 plant
1. Temperature	Not adaptable to high temperature.	Adaptable to high temperature.
2. Kranz anatomy	No seperate layer of mesophyll cells around bundle sheath of leaves.	Radially arranged thick layers of mesophyll cells around bundle sheath of leaves (Kranz anatomy).
3. Types of chloroplast	Structurally all chloroplasts are the same.	Structurally two types of chloroplast: (i) Mesophyll chloroplast with grana and (ii) Bundle sheath chloroplast without grana [/Large chloroplast with a few number of grana- Ref: Azmal]
4. Density of CO_2	Minimum concentration of CO_2 needed for photosynthesis is 50 ppm (parts per million) (50-150 ppm).	Minimum concentration of CO_2 needed for photosynthesis is 0.10 ppm. Requirement (0.10-10 ppm).
5. Reaction	Light dependent reactions and Calvin cycle occur in mesophyll cells.	Light dependent reaction occurs in mesophyll and Calvin cylce & production of CO_2 occur in bundle sheath cells.
6. Origin	It is assumed that most C_3 plants originated in relatively temperate regions.	It is assumed that most C_4 plants originated in tropical regions.

Differences between Calvin cycle and Hatch & Slack Cycle

Calvin cycle	Hatch & Slack cycle
(i) Occurs only in mesophyll cells.	(i) Occur in both mesophyll and bundle sheath cells.
(ii) Photorespiration occurs.	(ii) Photorespiration doesn't occur.
(iii) Primary CO_2 acceptor is RuBP.	(iii) Primary CO_2 acceptor is PEP.
(iv) CO_2-fixing enzyme is RUBISCO.	(iv) CO_2-fixing enzyme is PEP carboxylase.
(v) First stable substance is 3 PG (3-C).	(v) First stable substance is acetic acid (4-C).
(vi) Efficiency of carboxylase for CO_2 is medium.	(vi) Efficiency of carboxylase for CO_2 is high.
(vii) One type of chloroplast.	(vii) Two types of chloroplast (bundle sheath chloroplast has no developed granum).
(viii) Optimum temperature for this cycle is 10° to 25°C [inactive in excess intensity of light- Ref: Azmal]	(viii) Optimum temperature for this cycle is 30° to 45°C. [Active in excess intensity of light- Ref: Azmal]
(ix) Minimum requirement of CO_2 in atmosphere is 50 parts per million [50–150- Ref: Azmal].	(ix) Minimum requirement of CO_2 in atmosphere is 0.10 parts per million [10- Ref: Azmal].

লেগে থাকো সৎ ভাবে,
স্বপ্ন জয় তোমারই হবে।